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ARS CO-WY RESEARCH COUNCIL ANNUAL REPORT

1995

For Additional Information:

Ronald F. Follett, Research Leader
Soil-Plant-Nutrient Research Unit
301 S. Howes Street, Room 407
Fort Collins, CO 80521

TEL: (970) 490-8200
FAX: (970) 490-8213
FTS2000: a03rfollett
INTERNET: rfollett@lamar.colostate.edu

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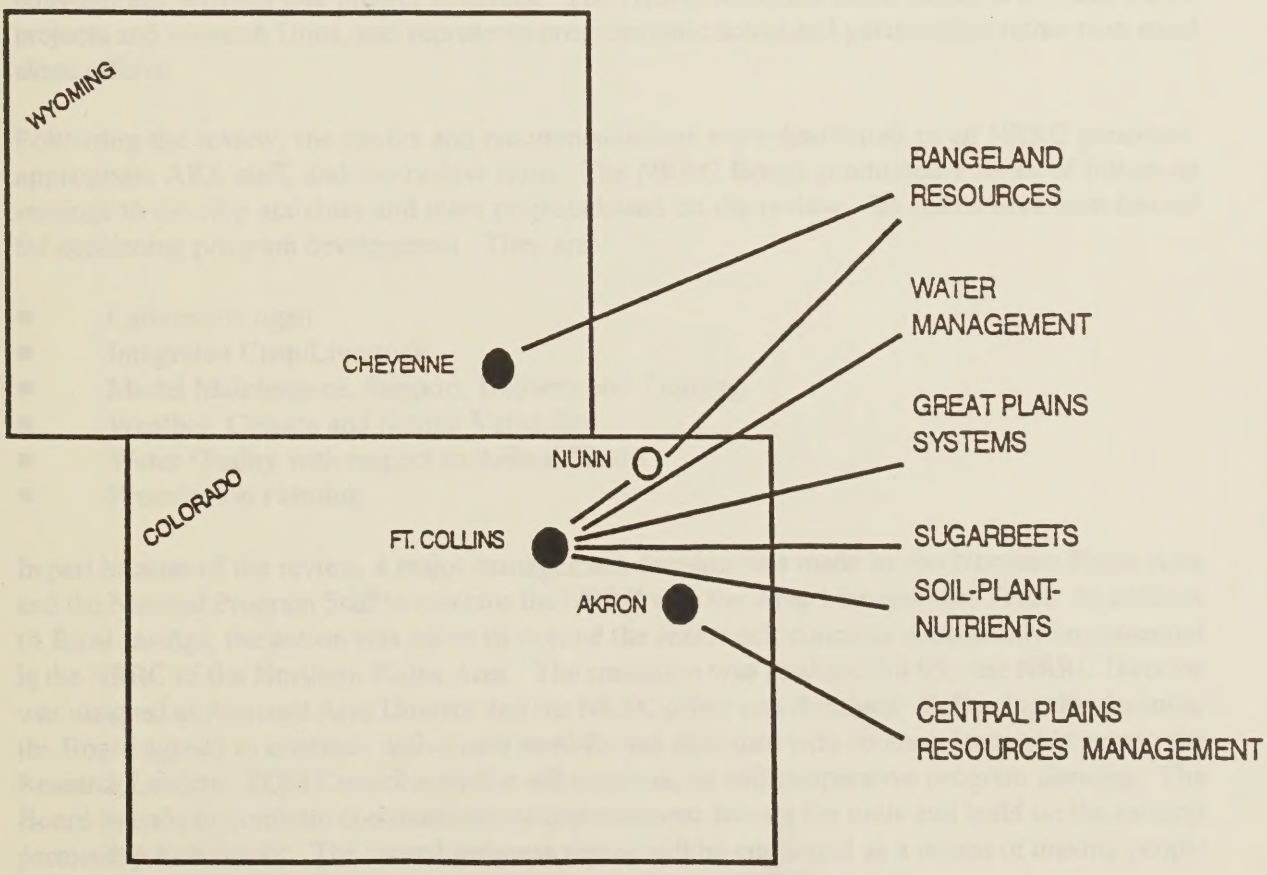
NORTHERN PLAINS AREA

CO-WY RESEARCH COUNCIL



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INTRODUCTION

NRRC PROGRESS REPORT

James R. Welsh

A major NRRC program review was held March 21-23, 1995. The review was designed to encourage comments on our current program. More importantly, the review team was asked to provide input on future research directions, from both continuing program and new priority perspectives.

Twenty eight review team members were carefully identified as representing a cross section of peer scientists, state and Federal agency partners and private sector customers.

For the review, research activities were organized into 6 research thrust areas, rather than by the more conventional scientist and project structure. The NRRC feels that much research is linked across projects and research Units, and represents programmatic teams and partnerships rather than stand alone efforts.

Following the review, the results and recommendations were distributed to all NRRC personnel, appropriate ARS staff, and the review team. The NRRC Board conducted a series of follow-up sessions to develop activities and team projects based on the review. Six teams have been formed for continuing program development. They are:

- Carbon/Nitrogen
- Integrated Crop/Livestock
- Model Maintenance, Support, Delivery and Training
- Weather, Climate and Spatial Variability
- Water Quality with respect to Animal Waste
- Prescription Farming

In part because of the review, a major management decision was made by the Northern Plains Area and the National Program Staff to combine the NRRC with the Area Management Team. In addition to fiscal savings, the action was taken to expand the teamwork concepts successfully implemented in the NRRC to the Northern Plains Area. The transition was finalized Jul 95; the NRRC Director was assigned as Assistant Area Director and the NRRC office was dissolved. Following this decision, the Board agreed to continue with a new semi-formal structure with rotating leadership among the Research Leaders. TQM Council activities will continue, as will cooperative program planning. The Board intends to continue communications improvement among the units and build on the existing partnership framework. The annual progress report will be continued as a means of making people aware of research activities among the Units in the former NRRC.

ARS CO-WY Research Council Staff - 1995

Dave Noroski, Utility Sys Operator

	Central Plains Resources Management	Great Plains Systems Research	Rangeland Resources Research Unit	Soil-Plant-Nutrient Research Unit	Sugarbeet Research Unit	Water Management Research Unit
Research Scientists	Randy Anderson Rudy Bowman David Nielsen Merle Vigil	Lajpat Ahuja, RL Jim Ascough II Jon Hanson Gregory McMaster Marvin Shaffer Lori Wiles	Gerald Schuman, RL Terrance Booth Gary Frasier Richard Hart Jack Morgan	Ronald Follett, RL William Hunter Gordon Hutchinson Arvin Mosier Lynn Porter	Earl Ruppel, RL Susan Martin Leonard Panella	Dale Heermann-RL Walter Bausch Gerald Buchleiter Harold Duke Edward Schweizer Roger Smith
Support Scientists	Curtis Reule	Patricia Bartling Mary Brodahl Gale Dunn Virginia Ferreira	Daniel LeCain Jean Reeder Ernest Taylor	Jorge Delgado William O'Deen		Richard Miskimins Kristine Stahll Nancy Stevens
Post Docs	Robert Aiken	Joseph Benjamin Hamid Farahani Howard Skinner Chuanguo Xu	Yuguang Bai John Reed			
Research Support Staff	Karen Couch Donna Diamond Michele Harms Albert Figueroa Donna Fritzler Linda Hardesty Stephanie Hill Cindy Johnson Marrietta Koch Mike Perry Gene E. Uhler	William Dailey Debora Edmunds Robert Erskine Michael Murphy Daniel Palic Harriet Rector Kenneth Rojas Lucretia Sherrod Bruce Vandenberg	Dern Ackerman Mary Ashby Leon Chea Stanley Clapp Pam Crane Pamela Freeman Larry Griffith Chris Mahelona Jeremy Manley Matt Mortenson Dennis Mueller James Pry Jeffrey Thomas Barry Weaver	Charles Andre Edward Buenger Susan Crookall Anita Kear Cathy Krumwiede Robin Montenieri Elizabeth Pruessner Julie Roth Mary Smith David Wright	Mary McClintock Patricia Noble Les Shader Johnny Thomas John Vasquez	Douglass Barlin Ted Bernard Michael Blue Daryl Carr Margaret Herzog Hubert Lagae Dean Santistevan

	Central Plains Resources Management	Great Plains Systems Research	Rangeland Resources Research Unit	Soil-Plant-Nutrient Research Unit	Sugarbeet Research Unit	Water Management Research Unit
Administrative Support Staff	Ginger Allen Llewellyn Bass Carolyn Brandon Linda Pieper	Julie Leppert Marlene Miller	Marcie Currie-Gross Ann Heckart Gloria Miller Kathleen Peterson	Stacey Wilkins	Marcie Currie-Gross	Maxine McCauley Lynnette VanGreuningen
Visiting Scientists/ Cooperative Staff	Mahdi Al Kaisi Scott Armstrong Mike Koch Manuel Rosales Josh Saunders Mike Sucik	Chad Bierbaum Lois Deer-Ascough Fritz Fiedler Amy Garrison Maurice Hall Jennifer Kochis Mahmood Nachabe Michelle Palic Steve Stadelmeier John Thomas Howard Thomas Howard Thompson Dave Wagner Huifang Yi	Dennis Noyes Wanda Orso	Airi Kulmala		

PROGRESS REPORTS

CENTRAL PLAINS RESOURCES MANAGEMENT RESEARCH UNIT

Randy L. Anderson, Research Leader
Central Great Plains Research Station
40335 County Road GG
P.O. Box 400
Akron, CO 80720
TEL: (970) 345-2259
FAX: (970) 345-2088

FTS2000: a03randerson@attmail.com
E-MAIL: rlander@lamar.colostate.edu

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CENTRAL PLAINS RESOURCES MANAGEMENT RESEARCH UNIT

CRIS PROJECT:

5407-12130-004-00 Dryland Cropping Systems to Improve Water and Nutrient Use Efficiency and Resource Protection

MISSION STATEMENT

To enhance the economic and environmental well-being of agriculture by development of integrated cropping systems and technologies for maximum utilization of soil and water resources. Emphasis is on efficient use of plant nutrients, pesticides, and water and soil convervation/preservation.

TECHNOLOGY TRANSFER - 1995

Central Plains Resources Management Research Unit

The staff participated in technology transfer by:

1. Sponsoring a Station Field Day on June 20, 1995. Approximately 100 producers, agricultural business representatives, USDA-SCS personnel, and CSU scientists attended.

2. Co-sponsoring an equipment field day with the Colorado Conservation Tillage Association on August 5, 1995. Approximately 50 producers attended.

3. Interacting with the USDA-NRCS by serving on the NRCS research committee, and writing fact sheets that summarize research data.

4. Serving on the Board of Directors for the Colorado Conservation Tillage Association, and participating in their annual winter meeting, where the staff presented information on fertility management and CRP takeout strategies.

5. Sponsoring the Maximum Economic Yield (MEY) Club at Akron, where bi-monthly meetings are held each winter. Staff presents research data to producers on cropping systems, alternative crops, nutrient management, and weed ecology.

6. Presenting data to Young Farmers Groups in the area. The groups are composed of beginning farmers.

7. Cooperating with the Eastern Colorado Range Station by guiding their cropping systems decisions and integrating cropping with livestock production. Presented cropping systems data at their annual winter meeting.

8. Hosting tours composed of foreign visitors, explaining our cropping systems and research systems.

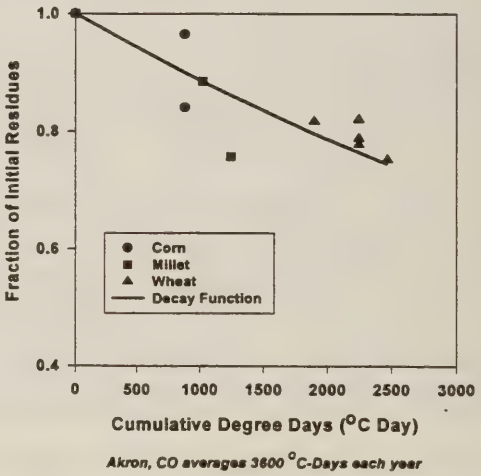
9. Presenting research data at the Great Plains Fertility Conference.

FIELD DECOMPOSITION RATES AND SOIL COVER OF SURFACE CROP RESIDUES

Aiken, R.M., M. Vigil, G. Uhler, M. Shaffer[1]

PROBLEM: Surface crop residues reduce soil and can improve soil water storage, conditioning the biological environment of crop seedlings and associated pests. Decomposition of surface residues reduce these benefits and may compromise conservation compliance required for commodity price support programs. Knowledge of environmental factors altering decomposition rates can guide surface residue management.

APPROACH: Seasonal decomposition rates of surface crop residues (wheat, millet and corn) are measured using litter bags, screen shelters and grab samples, collected at 1000 degree day intervals. Accumulation of surface crop residues in various wheat, corn and millet crop sequences was determined pre-plant and post-harvest over four crop seasons. We quantify daily temperature effects on decomposition rates using a first order rate model, scaled to thermal time (cumulative degree days).



RESULTS: Dry surface conditions and high carbon:nitrogen ratios resulted in similar decomposition rates among dryland grain crops. First order rate constants, scaled to thermal time, appear consistent for lab and field data available for wheat, corn and millet residues. The half-life of surface residues appears to be 5800 °C day, about 1.5 years of calandar time.

FUTURE PLANS: Field data collection will proceed to pre-plant tillage. We'll evaluate relationships among diagnostic residue attributes and environmental factors altering decomposition rates and soil cover. Manuscript reporting results will be submitted for publication, subject to peer review.

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[1] Shaffer: Great Plains Systems Research Unit, Fort Collins, CO.

SEASONAL RESIDUE IMPACTS ON RADIATIVE AND CONVECTIVE EXCHANGE PROCESSES

Aiken, R.M., D. Nielsen, L.R. Ahuja[1]

PROBLEM: Architecture of surface crop residues condition the habitat of crop seedlings and associated pests. Cooler and wetter soils, associated with no-till crop management, alter decomposition rates of surface residues as well as soil quality factors impacting water management. Knowledge of residue effects on surface microclimate and subsequent processes can guide soil and water management.

APPROACH: We installed radiation, temperature, wind and soil water sensors in 10 m x 30 m plots of standing wheat, millet, corn and sunflower residues following harvest. Hourly data acquisition is screened for sensor reliability prior to archiving for subsequent analysis. Sheltering and insulating effects of crop residues are quantified as solar reflectance and wind velocity at 0.2 m relative to reference wind speeds at 2.0 m. We quantify seasonal changes in residue architecture in a companion study.

RESULTS: Crop residues, plus soil, differ in absorbed solar radiation (1 minus reflectance) and in relative wind at 0.2 m. Higher daytime temperatures are expected within no-till wheat stubble due to greater absorbed radiation and wind reduction. Wheat under reduced till (sweeps cultivation) offers least protection to evaporative demand. The modest wind protection indicated for sunflower stems is likely an artifact of insufficient plot size. Previous measurements in farm-scale fields indicate relative wind speed of 0.4 to 0.5 within standing sunflower stalks. A similar "fetch" constraint could modify relative wind within corn as well.

Crop Residue	Solar Reflectance	Relative Wind Speed
Wheat-NT	0.24 (0.01)	0.420 (0.022)
Wheat-RT	0.23 (0.01)	0.746 (0.022)
Corn	0.29 (0.01)	0.595 (0.020)
Millet	0.27 (0.01)	0.678 (0.042)
Sunflower	0.26 (0.01)	0.672 (0.022)

FUTURE PLANS: Data acquisition will continue to pre-plant tillage for the subsequent crop. We'll evaluate relationships among residue attributes (reflectance, silhouette factor, etc.), and exchange processes (radiation, convection). Data will provide independent evaluation of energy balance modules of the Root Zone Water Quality Model for winter and non-freezing conditions. Manuscripts reporting results will be submitted for publication, subject to peer review.

[1] Ahuja: Great Plains Systems Research Unit, Fort Collins, CO.

STRUCTURAL COMPONENTS OF STEM STRENGTH FOR WHEAT CULTIVARS

Aiken, R.M., M. F. Vigil, G. Dunn[1], J. Shanahan[2]

PROBLEM: Standing crop residues insulate the soil from erosive and evaporative winds in semi-arid climates. These benefits decline as strong winds blow over decaying residues. Variation in stem strength alter susceptability of crop cultivars to lodging as well. Rapid quantitative screening tools indicating stem persistance can enhance selection of superior cultivars.

APPROACH: Quantitative measures of stem strength provide tools for evaluating cultivar susceptability to lodging and standing stem persistance. We used the cantelever principle to measure structural components of stem strength (shape factors and intrinsic strength) for the upper three internodes of nine wheat cultivars. We also determine biochemical properties of internode segments.

RESULTS: Preliminary results indicate the intrinsic strength of wheat stems is similar to that of wood. Variation in stem strength among wheat cultivars appears to result from diameter and thickness of stem walls. Rapid and inexpensive stem strength measurements could be incorporated in varietal selection programs.

FUTURE PLANS: We will test for significant differences in stem strength among the selected cultivars. Also, we'll evaluate the relationships of stem strength components with biochemical fiber analysis and field lodging observations of the selected cultivars. Manuscript reporting results will be submitted for publication, subject to peer review.

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[1] Dunn: Great Plains Systems Research Unit, Fort Collins, CO.
[2] Shanahan: CSU Soil and Crop Science Dept., Fort Collins, CO.

CORN YIELD RESPONSE TO DIFFERENT IRRIGATION, FERTILIZER RATES, AND PLANT POPULATIONS

Mahdi Al-Kaisi

PROBLEM: Irrigation and nutrient management are concerns in irrigated agriculture where the potential of groundwater contamination is great. The increase in fertilizer use creates concern regarding ways of managing nutrients, especially nitrogen, more efficiently. The other concern which prompted this study is water use efficiency. Proper water management is a key for improving yield, nutrient use efficiency, and groundwater quality.

APPROACH: The experiment was conducted on the Irrigation Research Farm in Yuma, Colorado, during the summer of 1995. Corn (Pioneer 3514) was planted on 15 May, 1995, on 14 acres (sandy loam) under a center pivot sprinkler system (LEPA). The variables included in this study are: three rates of water application (irrigation + rainfall) of 15, 20, and 25 inches, three rates of fertilizer of 125, 225, and 325 lb /a of nitrogen, and three corn populations of 23,000, 28,000, and 33,000 plants/a.

The treatments were randomly assigned to each plot in three replications in split-split-plot arrangements, with irrigation rate as the main plot. Corn population and fertilizer rate were the sub-plots. Irrigation scheduling was conducted according to daily crop water use (ET). Nitrogen was applied as follows:1) 20 lb N/a as a starter at planting on all plots, 2) 50 lb N/a was applied after emergence on all plots through the sprinkler system, and 3) The balance of N of each treatment rate was applied during the growing season through the sprinkler system, according to schedule, up to tasseling. Measurements for initial and at harvest soil nitrate, dry matter, LAI, grain yield, and soil moisture are collected.

RESULTS: Grain yield from all treatments was low due to several factors such as late planting, early wet spring, and unseasonably low temperatures early in the season.

Statistical analyses of yield data show significant difference in yield due to irrigation rates, nitrogen rates, and plant populations. The combination effect (interaction) of irrigation rates and plant population show no significant impact on yield under a low rate of water application. However, the interaction of irrigation and nitrogen rates affected yield .significantly (level of significance is: pr>F=0.0004). In contrast, the interaction of irrigation and plant population shows no significant difference in yield (level of significance is: pr > F =0.5410), which means there will be no substantial increase in yield due to increase in plant population over 27,000 plants/a under the same irrigation rate.

Water use efficiency refers to how many bushels of grain are produced per inch of applied water. Our results show no significant difference in water use efficiency between the three rates of irrigation. The increase in the nitrogen rate over 224 lb/a and plant population over 27,000 plants/a did not produce a significant increase in water use efficiency (bu/in).

FUTURE PLANS: The experiment will continue for the next 2-3 years similarly.

CROP HISTORY EFFECT ON WEED POPULATIONS IN SUMMER ANNUAL CROPS

R. L. Anderson

PROBLEM: Cropping patterns are changing in the Central Great Plains from wheat-fallow to more intensive crop rotations. One major contributing factor leading to this change in cropping is the replacement of tillage operations with herbicides for weed control.

However, public environmental concerns with the use of herbicides may limit or even eliminate future herbicide options. Secondly, several crops grown in this region do not have registered and effective herbicides for in-crop weed control. Because of these potential limitations, producers will need to use non-chemical weed control methods, including management practices that minimize weed seed production within the crop. Minimizing weed seed production in one crop may reduce weed populations in future crops, and subsequently reduce the need for herbicides.

The objectives of this study are: 1) determine the effect of cultural practices in winter wheat on weed populations in summer annual crops (oat for forage, corn, proso millet, and sunflower) planted the following year; and 2) rank crop response to wheat cultural systems in relation to weed population dynamics.

APPROACH: Three cultural systems are being compared: 1) Tam 107 at 675,000 seeds/acre planted in 12-inch rows, N at 60 lbs/ac applied in August before planting (conventional practices); 2) Lamar at 1 million seeds/ac planted in 12-inch rows, N applied in April before planting; and 3) Tam 107 at 1 million seeds/ac planted in 7-inch rows with N split applied: 45 lbs in April + 15 lbs with wheat seed at planting. Oat, corn, proso millet, and sunflower will be planted in 1996.

Summer annual weeds: redroot pigweed, kochia, Russian thistle, witchgrass, and green foxtail, were seeded at 200 seeds/m^2 in designated sites. Weed populations at wheat harvest and system effect on wheat yields were measured.

RESULTS: Weed population within wheat differed among cultural systems. Green foxtail population was reduced 63% with system 3 and 29% by system 2. Similar reductions occurred with redroot pigweed. The denser canopies of wheat in systems 2 and 3 minimized weed germination, seedling survival, and seedling growth. Wheat grain yields were highest with system 2, where Lamar was planted, yielding 43 bushels/acre, while yields for systems 1 and 3 (Tam 107) were 28 and 35 bushels, respectively. The spring was cooler than normal, and cool temperatures during pollination reduced seed set of Tam 107.

FUTURE PLANS: This project is part of an overall systems project that is developing production systems relying on weed management that prioritize cultural practices before herbicides for weed control.

CULTURAL SYSTEMS FOR WEED CONTROL IN PROSO

R. L. Anderson

PROBLEM: Proso currently has limited herbicide options for in-crop weed control. Also, environmental concerns about the use of pesticides has generated an interest in developing weed management tactics that do not rely on herbicides. Cultural practices, such as increased seeding rates, narrower row spacing, and taller varieties, have been used to minimize weed interference in other crops. Most research with cultural practices usually focuses on the effect of one or two practices in relation to weed control, but does not evaluate systems based on several cultural practices in combination. This study is examining the impact of individual cultural practices on weed-proso interactions, and subsequently, impact of cultural systems composed of several practices on weed control in proso. The ultimate goal is to develop a cultural system that will eliminate the need for herbicides or if needed, will favor reduced rates of herbicides.

APPROACH: Three tillage treatments were compared for effect on weed emergence: no-till, minimum till, (one sweep plow tillage in late May), and reduced-till, (tillage in April and late May). Weed emergence was recorded weekly during the growing season in designated m^2 sites.
In a second study, N fertilizer (ammonium nitrate) was applied in at two times (April and before planting). At both application times, N rate was either 40 lbs N/ac or 35 lbs + 5 lbs banded with proso seed at planting. A control of no N was included for comparison. A third study compared Cope, a tall variety, with Sunup, a short variety, both planted at two rates: 10 and 20 lbs/ac. For all studies, redroot pigweed was the main weed infesting the plots. At proso harvest, 10 pigweed plants per plot were harvested for biomass and seed production. Along with grain yields, proso biomass was determined.

RESULTS: Tilling the soil increased seedling emergence by 42% and weed populations at harvest by 29%. Proso grain yields did not differ among tillage treatments. All nitrogen treatments favored weed growth, with weed biomass increased 2-fold compared to the control of no N. In spite of increased weed growth, N still increased proso grain yields 20% compared to the control.

By growing a tall variety, Cope, and increasing seeding rates, redroot pigweed biomass was decreased by 62%. With Sunup, planting 20 lbs seed/ac resulted in 39% biomass reduction of redroot pigweed. Grain yield was highest with Cope, with yields being 13 to 18% higher than Sunup. This yield difference reflects Cope's more competitive canopy with redroot pigweed.

FUTURE PLANS: Cultural systems comprised of combinations of seeding rate, planting date, variety, row spacing, tillage systems, and reduced herbicide rates will be tested with the goal of developing low herbicide input production systems for proso millet.

WILD BUCKWHEAT ECOLOGY AND INTERFERENCE IN WINTER WHEAT

R.L. Anderson

PROBLEM: Wild buckwheat is a prevalent weed in the Central Great Plains, and causes significant yield losses in wheat and proso millet. Herbicide options exist for wild buckwheat, but environmental concerns have stimulated a more balanced approach to weed control, where cultural practices are incorporated with herbicide options into management systems. Developing effective integrated management systems for specific weed species requires knowledge about ecological characteristics such as time of seedling emergence, rate of seedling development, and peak growth periods.

This study is characterizing wild buckwheat's ecological characteristics and developing a yield loss equation based on wild buckwheat populations in winter wheat.

APPROACH: Emergence pattern was determined by counting weekly seedling emergence form five 1-m^{-2} sites. Ten seedlings of wild buckwheat were established in winter wheat starting on April 1 and weekly until May 5. Development was monitored weekly, and biomass and seed production measured at winter wheat harvest.

To determine wild buckwheat rooting depth , `Tam 107' winter wheat and wild buckwheat were planted in the following sequence: Tam 107 alone, wild buckwheat alone, Tam 107 + wild buckwheat, and a control of no plants. Neutron probe readings, from access tubes placed in the center of each plot, were taken weekly, starting on April 1.

Wild buckwheat was established at: 5, 10, 25, 50, 100, and 200 plants/m^{-2}, into Tam 107 (planted at 45 kg/ha). Plots were split, with a control included for each population. Yield loss equations based on infested populations were examined..

RESULTS: Wild buckwheat emergence has been recorded over three years, with emergence varying considerably among years. Peak emergence (> 90% of total emergence) occurred between April 28 and May 12 in 1993, April 7 and May 16 in 1994, and May 20 and June 14, 1995. Daily air temperature averages were similar for initiation of emergence among all years: daily maximum averaging 61.5 F for the seven days preceding emergence, and daily minimum being 33.5 F. Because of the wet and cool spring in 1995, wild buckwheat plants did not survive when planted in April or early May. Also, because of the late emergence in 1995, wild buckwheat interference did not reduce winter wheat yields. Wild buckwheat rooting depth was shallow, indicating that nitrogen placement deep in the soil profile will favor winter wheat over wild buckwheat.

FUTURE PLANS: This study will be repeated, then published in Weed Science.

INTEGRATING CROPPING SYSTEMS WITH LIVESTOCK SYSTEMS

D. Schutz[1], T. Stanton[1], and R. Anderson

PROBLEM: The Central Great Plains Resource Management Research Unit is exploring alternative cropping rotations, with the goal to increase cropping intensity and consequently, cropping diversity. The CSU Eastern Colorado Research Center (ECRC) at Akron (Range Station) is exploring alternative feeds for effect on weight gain and overwintering of livestock. Inclusion of livestock in the overall production system not only increases potential use and market for alternative crops, but also serves as drought insurance (poor grain crops could be turned into forage). The purpose of this team effort is to implement alternative cropping systems at ECRC for better utilization of crop aftermath and alternative forages while reducing annual cow costs.

APPROACH: Studies are evaluating the effect of triticale production for forage on economics of annual cow costs. Cattle grazing triticale forage in the spring are being compared to cattle maintained on standing dormant winter native range and supplemented with protein to determine if overwintering costs can be reduced.

We are also evaluating harvest efficiency of cattle grazing foxtail millet in swaths versus baling and feeding hay. Cattle were placed on the experimental site during the month of December, with daily weight gain and body condition score change being calculated.

A third study is evaluating intercropping corn and sunflowers for silage quality. Corn and sunflower were planted alone and also in alternating rows. Planting date was May 16, with prowl applied without incorporation for weed control.

RESULTS: Producers can extend their winter range feed supply by growing foxtail millet and triticales. Triticales was grazed for 45 days in the spring, yet grain yields were not detrimentally affected. Triticales begins spring growth earlier than either the winter range or winter wheat, and supplies high protein forage before the range grasses initiate growth. Cattle weight gain is greater when triticales is included compared to winter range alone.

Fall harvesting of foxtail millet extends the fall feeding season. The efficiency of cattle harvesting swaths remaining on the ground is sufficient to be more economical than baling and feeding cattle from a systems perspective.

Silage quality of sunflower is superior to corn, while tonnage is greater with corn. The intercropping of corn and sunflower improves quality while still producing high tonnage of feed.

FUTURE PLANS: This study's long-term objective is to develop integrated production systems for diversified farms.

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[1]Schutz and Stanton are in the Department of Animal Sciences at CSU.

EVALUATION OF ALTERNATIVE CROP ROTATIONS TO WINTER WHEAT - FALLOW

D.C. Nielsen, R.A. Bowman, M.F. Vigil, and R.L. Anderson

PROBLEM: Producers in the Central Great Plains practice a rotation of winter wheat - fallow. Fallowing degrades soil by increasing loss of organic matter and organic nitrogen while exposing soil to wind and water erosion. Producers can counter this trend in soil degradation by cropping more frequently. Producers in semiarid regions rely on fallow to stabilize their crop production. However, improved weed control methods during non-crop periods have increased precipitation storage efficiency, thus producers have more available soil water for crop growth. Also, new crop varieties are more efficient in converting water into grain, thus the need for fallow may be less than historically perceived.

This study is evaluating crop rotations to increase cropping intensity and subsequently, reduce the amount of fallow.

APPROACH: A crop rotation study of 23 rotations was initiated in 1990 on a Weld silt loam at the Central Great Plains Research Station. With all rotations, we are minimizing tillage. With some crops (sunflower and safflower), tillage is required to incorporate herbicides. Three tillage systems, conventional-, reduced-, and no-till, are included in the wheat - fallow rotation as a basis for comparison in soil quality changes. Standard agronomic practices for seeding rates, planting dates, varieties, and weed control are being followed.

RESULTS: To compare the biological productivity of each rotation, yields are expressed on an annualized basis, where the fallow investment is included in calculating yields. Therefore, if wheat - fallow produces 40 bu/ac, the annualized yield is 20 bu/ac/yr, as one half of the producer's land is not producing grain (in fallow). Averaged over 1993 to 1995, the wheat - fallow rotation yields 1140 lbs of grain/ac, while a wheat - corn - proso rotation yields 1680 lbs of grain/ac. The second most productive rotation is wheat - proso millet. These two rotations yield 46% more grain on an annualized basis than wheat - fallow.

Regressing annualized yields on cropping intensity shows that for this site, maximum biological yield potential occurs when 80 to 90% of the land is cropped. This intensity level would reduced the amount of fallowing to only 10 to 20% of the crop land in any one year.

Corn yields are most stable when planted after winter wheat. Growing corn in rotation with black turtle bean appears to be unsuitable for this region, as the bean does not produce any residue. This lack of residue alters the water relationship such that the 1995 corn yields in bean residue was only 14% of corn yields in wheat stubble. Wheat yields planted after fallow versus into millet residue (without fallow) differed by 42%.

FUTURE PLANS: Yield data has been shared with the GPSR Unit for use in their GPFARM decision-aid model. We are examining residual N buildup in soil of selected rotations.

WEED SUPPRESSIVE CANOPIES IN SUNFLOWER

D.L. Tanaka[1] and R.L. Anderson

PROBLEM: Producers are seeking production practices that reduce pesticide use for economic and environmental reasons. Cultural practices, such as narrow rows and increased plant populations, may enable producers to enhance crop competitiveness to weeds. For example, by reducing row spacing from 76 to 38 cm and doubling the planting population of corn, producers can reduce herbicide use in the Eastern U.S. by 75% without reducing weed control. These cultural practices also may work with sunflower. Sunflower seed yields have been consistent over a wide range of plant populations, while research with row spacing shows either similar yields or a trend towards improved yields with narrower rows. This response to row spacing has been similar in both the Northern and Central Great Plains. Therefore, this study is comparing the effect of row spacing and plant population on light penetration within the sunflower canopy, weed biomass production, and seed yields of sunflower.

APPROACH: The study was conducted at Akron, CO and Mandan, ND in 1995. At Akron, sunflower 'Triumph 586' was planted by hand in 18- and 30-inch rows on June 21. Two populations were established with each row spacing: 16,000 and 20,000 plants/ac. Nitrogen as ammonium nitrate was applied at 50 lb N/ac after planting. Plot size was 9 by 15 feet. Soil was a Weld silt loam.

Photosynethically active radiation (PAR) was measured three times a week with the AccuPAR sensor probe (Decagon Devices, Inc., Pullman WA) until sunflower flowering. The probe was placed diagonally across two rows of sunflower, thus averaging light penetration within and between the two rows. Average PAR above the canopy was also measured for means of comparison. Measurements were taken within one hour of solar noon.

Seed yield, head diameter, and stalk biomass production were measured at maturity. Oil concentration was determined at a commercial laboratory and standardized to a 10% moisture basis.

RESULTS: Light interception was reduced by 15% with 18-inch rows at all dates of measurement at Akron. Plant population within a row spacing did not affect light penetration, therefore, data were averaged over populations. This reduced light penetration by narrow rows lead to a 50% reduction of weed biomass within the sunflower canopy. Grain yield, oil content, and residue production were not affected by row spacing or population. The use of narrow rows offers potential in reducing weed competition in sunflower.

FUTURE PLANS: We will compare cultural systems for weed management in sunflower. The systems will be comprised of N placement, delayed planting, narrow rows, and high seeding rates. Herbicide rates will be reduced in conjunction with the various cultural systems.

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[1]Tanaka: USDA-ARS, Mandan ND.

EXPOSURE OF RUSSIAN WHEAT APHID INFESTED WINTER WHEAT TO THE ICE NUCLEATING BACTERIA *P. syringae* AND COLD TEMPERATURE

J.S. Armstrong and M. D. Koch

PROBLEM: Recent experiments have demonstrated that when Russian wheat aphids (RWA) are exposed to the ice nucleating bacterium *Pseudomonas syringae* in the presence of subzero temperature, their supercooling capacity is elevated significantly (5 - 21^{0}C) (Armstrong et al. 1996). This experiment goes a step further in determining if *P. syringae* can be used in a spray solution to reduce the RWA's ability to survive the winter environment. RWA infested plants were sprayed with solutions of freeze-dried *P. syringae* and exposed to subzero temperatures.

APPROACH: On 3 January 1995, a total of 20 'Tam 107' plants were cored from a field on the research station, placed in the greenhouse and artificially infested with RWA nymphs. After the RWA colonies increased and symptomatic tillers appeared (Feekes 4, 17 January), the pots were placed outside and sprayed with different amounts (25, 50, 100mg of bacteria/ml of water) of the freeze-dried bacteria in distilled water. The bacterial dilutions were applied at 5:00PM, 17 January 1995, and left outside overnight. The canopy temperature of the wheat plants was measured every ten minutes, then averaged to one hour. The hourly max and min temperatures were also recorded. The following day, plants were placed inside the greenhouse for four hours to allow any aphids that did survive some time to "recuperate". Percent mortality was then calculated.

RESULTS: The exposure temperature declined from 19.0 to -7.0^{0}C in the first two hours and stayed below 0^{0}C for the remaining 14 hours. The coldest stretch of temperature occurred between 6:00AM and 8:00AM on the 18th, where it stayed between -9.0 and -10.0^{0}C. RWA mortality was highly variable, with the 50 mg/ml dosage causing the highest mortality (94%). The check plants (untreated) had 35% mortality indicating that the outdoor temperature was low enough to cause some mortality without the bacterium. We believe the variability of mortality in this study is due to the fact that some aphids were exposed to the bacterium while others were not. This is a function of the fact that some the aphids were inside the curled leaf and not exposed, thus their supercooling capacity was not affected.

All plants in this experiment were dead within one week as determined by the absence of any green tillers or leaves. The same held true at four weeks. This might be expected since the plants were acclimated to the greenhouse and not the outdoor temperatures.

FUTURE PLANS: From previous experiments, we can elevate the supercooling capacity of the RWA with *P. syringae*. However, we must find an effective application method for the treatment to be applicable.

DEVELOPMENT OF A DEGREE-DAY BASED PREDICTION MODEL FOR ADULT SUNFLOWER STEM WEEVIL, *Cylindrocopturus adspersus,* EMERGENCE

J.S. Armstrong

PROBLEM: During the 1993-1994 & 1994-1995 growing seasons, the sunflower stem weevil (SSW) was an epidemic problem in the Central Great Plains Growing area. Sunflowers grown on the Research Station at Akron suffered as high as 80% pre-harvest lodging (1994) from SSW infestations that reached as high as 80 SSW inside one stalk. Surveys of producers fields surrounding the Research station resulted in similar infestations. This insect is difficult to scout for because of its small size and behavior of dropping to the ground when the host plant is disturbed. Since this is a new pest, producers and agriculturalist are simply not accustom to scouting for it.

Until improvements are made in the detection and scouting for the SSW, the most reliable method of predicting adult emergence in the spring would be with a heat unit based degree-day model. The base temperature (above which growth and development of SSW occurs) is 5^0C. In addition to the base temperature, the daily max and min temperatures and the number of adults emerging from SSW infested sunflower stalks are all that is needed to correlate degree-days with SSW emergence.

APPROACH: Six sets of ten sunflower stalks from 1994 crop residue were collected and placed under six screen cages on 7 April 1995. The cages were monitored every two to three days from mid May through July for adult SSW. All adults were removed from each cage on each sample date. The max and min temperatures from 1 January through 31 July were obtained from a National weather service station approximately 100 meters from the emergence cages. Degree-day accumulations were calculated by (max+min)/2-5^0C.

RESULTS: Six SSW emerged on 6 June. Degree-day accumulation at this time were 379 (Table 2). The largest number of SSW emerged between 25 June (50% emergence complete) and 29 June (90% emergence complete) SSW emergence was complete by 11 July or 744 degree-days. It should be noted that precipitation during this study was significantly above normal, and degree-day accumulations would be behind normal because of a significantly cooler spring.

FUTURE PLANS: This was the first years data from a three year study. Future plans for this research include studying SSW emergence at several different sites where the max and min temperature can be recorded. In addition to the Akron site, cooperators have been identified in the Burlington, Goodland, and Scottsbluff areas. This will help in more closely defining the correlation between degree-day accumulations and SSW emergence.

WASP PARASITOIDS RECOVERED FROM SUNFLOWER PESTS OF THE HIGH PLAINS

J.S. Armstrong and M.D. Koch

PROBLEM: There is limited literature available to help identify parasitoids of sunflower pests in the High Plains Region. Native parasitoids (parasites dependent on a particular species for development) are natures biological control of pests populations. We felt it was important to rear as many parasitoids of sunflower pests (sunflower stem weevil and sunflower head moth) as possible for future reference. This report describes the recovery, identification and percent parasitization of three parasitoids attacking specific sunflower pests.

APPROACH: On 22 March 1995, thirty sunflower stalks from 1994 crop residue, and heavily infested with spotted sunflower stem weevils were placed in a growth chamber (10^0C & dark for 8 hours, 21^0C & light for 16 hour). The sunflower stem weevils that emerged from the stalks were counted every two to three days along with any wasp parasitoids that emerged.

On 21 October, one hundred and fifty pupae of the sunflower head moth were collected from sunflower heads that had not been treated with any insecticide. The pupae reared to adults using the same procedures above.

RESULTS: A total of 131 sunflower stem weevils emerged from the sunflower stalks between 22 March and 27 April. A total of 15 wasp parasitoids from the family Pteromalidae were recovered form the stalks, and emerged just prior (7 to 11 March) to the first emergence of the sunflower stem weevil. The Pteromalidae were later identified by Larry Charlet (USDA Research Entomologist, Fargo N.D.) as *Neocatolaccus tylodermae*, which has been recorded as a parasitoid of the sunflower stem weevil in Texas, but not in Colorado. Another parasitoid was recovered (4 total) from the sunflower stem weevils. It was identified as *Nealiolus curculionis*, a wasp from the family Braconidae, and recorded as very common parasitoid of the sunflower stem weevil in North Dakota.

From the one hundred and fifty sunflower head moth pupae that were placed in the growth chamber, a total of 24 adult moths emerged from 27 October to 12 November. This low emergence of adults is probably due to a lack of cold acclimation that is normally required before pupation is completed. A total of 8 wasp parasitoids emerged from the pupae, and were identified as another Braconidae (*Macrocentrus ancylivorus*) (Rohuer). *M. ancylivorus* is a common parasitoid of the head moth from North Dakota to Texas.

FUTURE PLANS: We plan to rear as many different parasitoids of sunflower pests as possible to develop a reference collection that can be accessed by anyone working in sunflower pest management.

METHOD DEVELOPMENT FOR EVALUATING AND QUANTIFYING SOIL QUALITY

R A. Bowman and Mike Peterson[1]

PROBLEM: In the semiarid areas of the Great Plains, continued clean-till wheat-fallow cultivation of the native grasslands has resulted in significant losses of soil organic matter (SOM) because of wind erosion and decomposition. This loss of SOM results in a deterioration of soil quality and a reduction in crop productivity because of attendant losses in soil physical, chemical and biological properties such as rooting depth, water storage and soil aggregation. Total pools of organic C in croplands are sometimes inadequate as predictors of trends in soil deterioration because they may lack sensitivity over the short term (1 to 3 years); but over the long term, this may not be the case. A need exists, therefore, to develop methodology to assess soil quality changes and direction of change. The specific objective was to develop easy sensitive methods based on organic matter content and other soil parameters to assess soil quality, and consequently, long-term soil productivity in croplands.

APPROACH: The intent is to develop a quantitative index, which hopefully, will integrate losses in SOM due to erosion, decomposition, and nutrient uptake, and gains due to fertilization and net residue inputs and organic matter content from previous cropping. Besides measurement of SOM, labile organic C pools, enzyme activity, and other biologically based pools, bulk density (BD) and depth to lime (solum) were also measured. Thus, a Soil Quality Index (SQI) can be assessed based on comparison of top 15 cm of soil between new alternative cropping rotations (acr) and the conventional wheat-fallow or with an adjacent native sod.

RESULTS: We collected data for soil quality index (SQI) determination where soil organic matter (SOM) and bulk density (BD) at 15 cm depth, and the depth to lime (solum depth) values in the cropped plots were compared to that in the adjacent native sod. All relationships were deemed to be linear; thus, with other things being equal, a cropped site with 25 cm of solum had a SQI of 0.5 if the native sod was 50 cm deep. Since our solum depths varied the most (20 cm where erosion was severe to 90 cm where we had a buried B horizon), this parameter (solum depth) influenced SQI more than SOM or bulk density. Values for SQI for our alternative crops rotation (ACR) plots varied from 0.38 in a highly eroded area to 1.10 where solum depth was deeper than that in the native sod, and SOM was almost as high. A regression analysis was done on yields and SQI. Although the data were highly variable, lower yields for corn, millet, and wheat were found in rep 3 than in the other 2 reps. Generally, rep 3 showed greater erosion (lime at shallower depths) and lower SOM values than rep 1 or 2.

FUTURE PLANS: The soil quality index can best be used as a management tool over time. Thus, its evaluation would only be needed every 3 to 5 years. The direction of change for each farm, county, or region is an important indicator of management histories and long-term sustainability at the unit or regional level. With the cooperation of selected farmers, we are initiating an evaluation of the SQI in Washington county, and across Northeastern Colorado.

[1]Peterson: USDA-NRCS, Greeley, CO.

SOIL ORGANIC MATTER DYNAMICS UNDER ALTERNATE CROPPING AND TILLAGE SYSTEMS

R. A. Bowman, M. F. Vigil, R. L. Anderson, and D. C. Nielsen

PROBLEM: Soil organic matter is important to hold the soil together, to easily infiltrate water, to reduce compaction, and to provide nutrients such as N, P, K, S, and micronutrients. However, the conversion of Great Plains grassland to clean-till small grain farmlands since the mid 19th century has resulted in extensive loss of the native SOM because of wind erosion and decomposition. On a global basis,with about 40% more organic carbon residing in the SOM than in the terrestrial plant biomass, it is easy to see how the conversion of grassland to wheat-fallow could create over time a drop in crop production and a significant increase in global CO_2. On the other hand, if we intensify the cropping system over the WF, and minimize soil disturbance through less tillage, and if we manage water, fertilizer, and pests efficiently, we should be able to reverse SOM loss and increase soil productivity. Our objective, therefore, was to evaluate different cropping systems for their efficiency in water and nutrient use, minimal soil erosion, minimal chemical leaching, and organic matter buildup.

APPROACH: The study is located at Akron CO on a Weld silt loam. Three replications of 60 combinations and permutations of cropping and rotation sequences exist (See report by Anderson, Nielsen, Bowman, and Vigil for treatments). Data was also collected on our long-term tillage plots (initiated in 1960s). Extensive sampling was conducted on all 180 sites for soluble (dichromate oxidation) and total organic carbon, total N (C N analyzer), and color absorbtivity at 550 nm of NaOH/EDTA extracts. Soil samples were collected at 0-5 cm (2 inches), and at 5-15 cm (4 inches) for stratification and for plow layer evaluations especially under the no-till conditions and mixing under conventional-till.

RESULTS: A direct comparison of same plots was conducted for SOM content in 1990 and 1995. The data showed an 8% increase in the top 15 cm for the 23 plots sampled. A comparison of tillage systems showed significant SOM differences (5% level) only at the 0-5 cm depth. Both no-till and reduced-till treatments showed a 14% increase in SOM over the conventional-till for this depth. Plots with greater cropping intensities (3- and 4-year rotations with fallow and continuous cropping) also showed higher SOM content at the 0-5 cm depth than the wheat-fallow. Data for stable aggregates showed a higher percentage of >2.00 mm, and >0.84 mm for no-till and reduced-till wheat-fallow than for conventional-till. However, the conventional-till site where lime was close to the surface showed greater cementing of particles and high stable aggregates. Long-term tillage plots showed high SOM values for oat-corn rotation, and low values for wheat-fallow (plow) at the 0-5 cm depth. The oat-corn plots are showing soil pH values around 5.6 compared to 6.4 for the other treatments.

FUTURE PLANS: We will be studying nitrate contribution from the soil organic matter, and fine-tuning our N recommendations based on profile N contribution. We will also evaluate soil sulfate and zinc status for oilcrops and corn.

P DYNAMICS UNDER ALTERNATE CROPPING AND TILLAGE SYSTEMS

R. A. Bowman and A. D. Halvorson

PROBLEM: No-till systems usually conserve more moisture than clean-till systems, especially when weeds have been controlled. The extra available water invariably results in greater yield benefits from N and P fertilizer, with corn requiring more water and fertilizer than wheat because of its higher dry matter production (50 bushel dryland wheat requiring about 75 kg N and about 12 kg P, with 80 bushel dryland corn requiring about 80 kg N and 18 kg P / ha). The role of water and nitrogen is being studied for efficient use. As cropping continues, other nutrients such as P and micronutrients which are seldom replenished, may become deficient. This need becomes even greater in the eroded areas of the Plains where P is chemically fixed by free lime, and where high P applications may also induce Zn and Fe deficiencies. The objectives of the research, therefore, are to evaluate P availability and cycling under WF and alternate cropping systems where more residue is returned to the soil surface, and consequently, more P recycled from within the soil profile. Information is needed for P use efficiency for subsequent crops such as corn and millet or oilcrops or legumes after wheat in a reduced-till rotation.

APPROACH: In a Weld silt loam, various soil P parameters were measured at the 0-5 and 5-15 cm depths to assess P availability and cycling in selected plots from our alternate cropping and tillage system study (ACR). These parameters included available P pools such as those extracted by bicarbonate and anion-exchange resins, total soil P, and total soil organic P, residual P and phosphatase activity which is a measure of quickly available organic P. Phosphorus in the soil profile to 120 cm is also assessed in our long-term tillage plots.

RESULTS: As cropping intensity increased, there was a trend for more labile P (resin-extractable, and bicarbonate-extractable) to accumulate at the 0-5 cm depth because of recycling from residues. Because of mineralization of P from residue and SOM in the summer months, the sum of the inorganic and organic P extracted in bicarbonate gives a better measure of plant-available P. At this time the P contribution of this residue or P from SOM is confounded from fertilizer P applications. In the long-term tillage plots the highest concentration of total P was found at the 60 to 90 cm depth at the lime interface. The data for organic P show a trend for some P movement within the profile.

FUTURE PLANS: Under no-till conditions, P from residue exists in a stratified layer at the surface. We need to conduct research to find out how available this P is without soil mixing. We will be evaluating early plant-P uptake under no-till to see the effects of stratification and cool soils with and without starter-P fertilizer. We also need to evaluate P use and need for eroded slopes in our dryland cropping system. For this study, we hope to include a granulated low-moisture sludge material.

COMPARISON OF CRP LAND IN VARIOUS STAGES OF REST WITH WHEAT-FALLOW AND ADJACENT GRASSLAND

R. A. Bowman and R. L. Anderson

PROBLEM: Present Center projects relevant to CRP address soil and vegetation changes on small station plots. Hopefully, with other things being equal, these small plots will reflect the changes occurring in the over 30 million acres of highly erodible cropland set aside in grass for at least 10 years as part of the Food Security Act of 1985. A principal question in this billion-dollar experiment is whether the rested cropland will be able to adequately support cropping again, and under what conditions or restraints this should be done. Obviously, if soil conditions are deemed inappropriate, a site could remain in grass. A main objective of this research, then, is to develop a set of criteria based on soil physical, chemical, and biological properties to determine adequacy for release of CRP lands back to cropping. An opportunity exists in Washington County to extend this field laboratory research to actual on-farm analysis of farmers' fields that have been in CRP for various lengths of time, the longest requiring three more years to complete its 10-year cycle. Data collected will reflect the true state of affairs and magnitude of change for these once fragile lands.

APPROACH: Six farms in Washington County on the CRP were selected from data obtained through NRCS. Two went into the program in 1986, two in 1988, and two in 1990. These farms were selected because they also had conventional wheat-fallow and native grassland sites nearby. Thus, one can simultaneously evaluate and compare changes under all three conditions: the original system (grassland or rangeland), the traditional farming system (winter wheat-fallow), and the CRP (regenerative system). Soil parameters measured included: organic carbon, TKN, available P, and pH. Soils were sampled at 0-5 and 5-15 cm with a minimum of three field replications with five composites.

Another study was initiated in 1994 and planted to corn in 1995 on old CRP land to assess the efficiency of grass take-out before renewed cropping, and to assess changes in soil quality. We compared various systems for sod control ranging from no-till to reduced-till, to conventional-till. After fallow wheat was planted into the plots. With one no-till treatment, we planted corn directly into the sod in the spring of 1995.

RESULTS: Data indicate that some form of tillage was necessary to control perennial grasses. This is especially true for corn planted into sod since Accent had to be used for control of grass which was not killed. With respect to SOM, the adjacent native sod contained about 2.0% SOM, the continuous wheat-fallow about 1.0%, and the CRP land about 1.4% SOM in the top 5 cm. A preliminary aggregation study was done on the surface 20 mm of soil to assess stable non-erodible aggregates (>O.84 mm in diameter). Results showed 22% stable aggregates for the sod, 18% for CRP, and 14% for the continuous wheat-fallow.

FUTURE PLANS: We will be collecting data on the 1986, 1988, and 1990 sites this spring, and also on the newly established cropped sites.

DETERMINING BEST ADAPTED CULTIVARS AND OPTIMUM DRYLAND PLANT POPULATIONS FOR ALTERNATIVE CROPS

David C. Nielsen

PROBLEM: Increased use of conservation tillage in the central Great Plains has increased precipitation storage efficiency and made more soil moisture available for crop production, thereby providing greater opportunities for more intensive crop production as compared with conventional wheat-fallow. Future successful and profitable agricultural production will likely be improved with increased diversity of production. The objectives of this experiment were to determine best adapted cultivars and optimum plant populations for alternative crop species.

APPROACH: Potential adapted alternative crops are continuously being identified through contacts with other researchers conducting similar investigations in other areas of the country, and through literature review. During the 1995 growing season four dry bean cultivars, three chickpea (garbanzo bean) cultivars, and one lentil cultivar were evaluated, each at two seeding rates. The two seeding rates were higher and lower than recommended rates from other sources. Garbanzo bean and lentil were planted late (19 May) due to very wet spring conditions. with a row spacing of 10". Beans were also planted late (28 June), with a row spacing of 22". Chickpeas and lentils were harvested on 5 Sep., and beans were harvested on 8 Sep.

RESULTS:

Crop	Variety	Population seeds/acre	Yield lb/acre	Crop	Variety	Population seeds/acre	Yield lb/acre
Chickpea	Sanford	113,030	364	Black bean	906	88,900	851
Chickpea	Sanford	56,520	108	Black bean	906	43,840	711
Chickpea	Tammany	113,700	1253	Black bean	Midnight	91,710	717
Chickpea	Tammany	56,850	905	Black bean	Midnight	45,220	873
Chickpea	UC27	113,210	1586	Pinto bean	Fisher	91,710	233
Chickpea	UC27	56,600	1490	Pinto bean	Fisher	42,220	294
Lentil	Brewer	1,217,390	543	Pinto bean	Othello	94,700	838
Lentil	Brewer	608,700	511	Pinto bean	Othello	46,700	783
				Tepary bean	Blue Spk.	104,960	962
				Tepary bean	Blue Spk.	51,760	1342

Extremely dry conditions during pod development and grainfilling limited pinto and black bean yields. Poor germination thin stands due to lack of seed fungicide treatment severely limited Sanford chickpea yields. Poor stand establishment occurred in all crops due to very wet soil conditions and poor seed slot closure.

FUTURE PLANS: The experiment will be conducted similarly next year with more normal planting dates.

WATER USE, YIELD AND AGRONOMIC PRODUCTION OF ALTERNATIVE CROPS UNDER AN IRRIGATION GRADIENT

David C. Nielsen

PROBLEM: Increased use of conservation tillage in the central Great Plains has increased precipitation storage efficiency and made more soil moisture available for crop production, thereby providing greater opportunities for more intensive crop production as compared with conventional wheat-fallow. Future successful and profitable agricultural production will likely be improved with increased diversity of production. Adding new crops to the traditional crops grown in this area will increase diversity. There are many unknowns associated with diversifying agricultural production with alternative crops, such as water requirements, water use-yield functions, rooting patterns, and water stress effects on plant growth, development, and yield.

APPROACH: Heavy spring rains delayed planting opportunities, so that we were limited to only working with dry beans and kenaf in 1995. Crops tested during the 1995 growing season were black turtle beans (Midnight), blue speckled tepary beans,pinto beans (Othello, Fisher), and kenaf (Everglades 41). Kenaf was planted 27 June and beans were planted 28 June. The plot area was under a solid set, gradient irrigation system. Plots were arranged such that there would be 4 replications of 4 levels of irrigation, with the highest irrigation level being weekly replacement of evapotranspirational losses.

RESULTS: Othello pinto bean yields ranged from 953 to 3692 lb/a with ET of 8.55 to 19.54 in. Fisher pinto bean yields ranged from 94 to 1293 lb/a with ET of 8.26 to 17.79 in. Black turtle bean yields ranged from 260 to 1085 lb/a with ET of 8.51 to 17.29 in. Tepary bean yields ranged from 924 to 2405 lb/a with ET of 8.68 to 16.63 in. Kenaf forage yields (dry weight) ranged from 1702 to 3215 lb/a with ET of 7.01 to 11.22 in.

The early frost (Sept. 20-22) combined with the late planting date resulted in a very short growing season in which to make evaluations. Most of the beans did not have sufficient growing season in which to mature, such that the typical linear response of yield to evapotranspiration did not manifest itself.

FUTURE PLANS: We plan to continue this experiment with Othello pinto beans and kenaf, but adding lentils (cv. Brewer) and chickpea (cv. UC27). The kenaf will be grown to evaluate both total seasonal production vs. water use and regrowth after cutting for forage.

TIMING OF WATER STRESS EFFECTS ON BLACK TURTLE BEAN PRODUCTION

David C. Nielsen

PROBLEM: Black turtle bean is a dry edible bean variety that may have potential for the central Great Plains, but little is unknown relative to the growth and production potential of black bean under the dryland growing conditions in this area. Unknowns associated with black bean production are how water stress at various growth stages affects growth, water use, rooting patterns, yield, and yield components. Knowledge regarding the sensitivity of black bean to water stress at various growth stages can help to determine if it will be suited for this environment.

APPROACH: Black turtle bean (cv. Midnight) was grown in small plots that were covered by a rainout shelter during precipitation events. Three replications of four water treatments differing in timing of water application but not total amount applied were established. All plots received 7.25" of water over the growing season. Treatment 1 received equal weekly applications of water; Treatment 2 received no water during grain-filling; Treatment 3 received no water during flowering; Treatment 4 received no water during vegetative development. Evapotranspiration was calculated by the water balance method from neutron probe measurements of soil water content. Leaf area index (LAI) measurements were made with the LAI-2000 plant canopy analyzer.

RESULTS: Yields ranged from 2242 lb/a (TRT4) to 924 lb/a (TRT3). Stress during the reproductive stage reduced number of seeds per pod and pods per plant. Water stress during grainfilling (TRT2) reduced seed size. Water use was not significantly different among Treatmenst 1, 2, and 3. Evapotranspiration for TRT4, with stress during the vegetative growth stage, was significantly lower than the other 3 treatments by about 1.5", probably the result of lower leaf area development. Soil profile water extraction ranged from 9.01 inches (TRT4) to 10.45 inches (TRT). Soil water extraction in all four treatments occurred at all 6 measurement depths (down to 165 cm), indicating that these beans can extract water from fairly deep in the soil profile when the water is present.

The significant reductions in bean yield with water stress during either the reproductive or grainfilling stage make production under dryland conditions somewhat risky. This experiment started with a full soil water profile. Under conditions of more limited soil water availability, yields would be unprofitably low.

FUTURE PLANS: This experiment will be repeated next year.

WIND VELOCITY, SNOW, AND SOIL WATER MEASUREMENTS IN SUNFLOWER RESIDUES OF VARYING HEIGHT AND DENSITY

David C. Nielsen

PROBLEM: More accurate estimates of soil loss by wind will be possible using the new wind erosion model if wind velocity data for sunflower residues are obtained. The ability of sunflower residues of varying height and stalk densities to trap snow needs to be quantified, as well as the resultant changes in over-winter and spring soil water content to assess the production potential of dryland sunflowers grown in crop rotations in this region.

APPROACH: Sunflowers were planted in 30" rows (populations ranging from 10,600 to 26,100 plants/acre), and cut at harvest to 17" and 29", or laid flat on the soil surface. Wind velocities were measured with cup anemometers at 6.5' above the soil surface and at 3 to 6 heights within the standing stalks. A silhouette factor was calculated as stalk population * height * diameter. Stalk heights, densities, diameters, residue mass and percent cover were measured after harvest. Soil water content was measured after harvest and periodically throughout the winter and spring using neutron scattering and time domain reflectometry techniques. Snow depth was measured following each snowfall and/or period of high wind with potential for drifting.

RESULTS: The silhouette factor (ranging from 0 to 110) effectively scales all of the wind velocity profiles regardless of stalk height, population, or diameter. A simple relationship was derived to predict wind velocity at any height within standing sunflower residue. Reduced wind speeds in standing sunflower residues can increase snow catch by three to twelve times (depending on wind conditions during and after snow storm), potentially adding three inches more available water to the soil profile compared with areas where sunflower stalks were not left standing over winter.

Standing sunflower stalks are effective at reducing wind speed at the soil surface, and increasing snow catch, thereby reducing the potential for wind erosion and increasing precipitation storage efficiency. The relationship derived in this study predicts that for a field with a stalk population of 15,000 stalks/acre, stalk diameter of 1 inch, and stalk height of 27 inches (resulting in a silhouette factor of 103), adequate erosion protection would be provided for wind speeds up to 30 mph. The increased soil water content (a result of the increased snow catch) under the tall standing stalks has the potential to add up to 18 bu/a to a subsequent wheat crop. Even though amounts of residue produced by sunflower are low, NRCS should give proper credit to the wind reduction potential offered by standing stalks based on measured silhouette factor.

FUTURE PLANS: The results will be submitted to Journal of Production Agriculture for publication.

DRYLAND PRODUCTION OF RASPBERRIES WITH CROSS-LINKED POLYACRYLAMIDE (CLP) AND WEED/EVAPORATION BARRIERS

David C. Nielsen

PROBLEM: An alternative crop that may have potential as a cash crop in the central Great Plains is raspberries. The development and marketing of CLP, which has the ability to absorb and store large quantities of water, make the production of rainfed raspberries a possibility if sufficient water can be harvested from adjacent non-cropped areas and retained in CLP for later use by raspberry plants. A polypropylene weed barrier can enhancethe benefit of natural precipitation by suppression of weeds and evaporation. Various bed construction factors, rates of CLP, types of weed barriers, catchment area to bed area ratios, longevity of weed barriers and CLP, rainfall/yield relationships, costs of production, and revenues from sales of product will need to be investigated.

APPROACH: Raspberry beds were established in May 1993 on a grassed rangeland area with approximately 3% slope (sloped to the SW). 1993 Progress Report gives bed details. A split plot, randomized complete block design (3 replications) with presence of weed barrier as main plots and 3 levels of CLP as subplots was established. Plant heights were measured several times during the growing season. Raspberries were hand-picked twice each week.

RESULTS: October 1994 precipitation recharged the raspberry bed soil water. Most of the plants in the high CLP treatment in REP 1 did not survive the winter. Above average rainfall in April, May, and June kept the beds well supplied with water through the first half of the growing season. The rains stopped in late July, with only 0.72" falling between July 22 and September 8 (second driest in last 30 years). There was virtually no berry production for any of the treatments, with only a few berries ripening every few days over the period of August 2 to October 14. For the small berry production collected, we noted that the presence of weed/evaporation barrier increased yield, and the low CLP level (1 lb/plant) increased yield compared with the control (no CLP) or the high CLP level (4 lb/plant). Visual observations of bed soil water content indicated that hydrated CLP continued to exist in the high CLP treatment throughout the summer.

As in 1993 and 1994, plant growth during 1995 was enhanced by the presence of weed barrier. Weed barrier helps to make efficient use of rain that comes in very small amounts (< 0.25"). The very dry conditions during fruiting should have created ideal conditions for evaluating the effect of water stored in the CLP to help produce a berry crop. It is not clear whether the crop failure was due to the inability of raspberry to extract water from the hydrated CLP, or whether these beds have a soil element deficiency or need an amendment to correct ph.

FUTURE PLANS: We will continue measurements of plant height and leaf area and yield. We will do some soil tests to determine necessary fertilization or soil amendment requirements.

INFLUENCE OF LEGUME GREEN-MANURE ON WINTER WHEAT YIELDS

Merle F. Vigil, David Nielsen, and Rudy Bowman.

PROBLEM: With the exception of water, nitrogen (N) nutrition is the most important limiting input to profitable winter wheat production in the central Great Plains. Increases in N fertilizer costs have caused some farmers to consider alternative systems that include legumes as a source of N. Farmers need to know how these systems impact winter wheat yields and economic returns.

APPROACH: Two sites have been established in which the main plots consist of legume species: Austrian winter peas, spring field pea (cv. Trapper), Indianhead lentils and a no-legume-summer-fallow plot fertilized at four N rates 0, 30, 60, and 90 lb N/ac. Within each main-plot, four sub strip plots are maintained which consist of four legume growth termination dates spaced two weeks apart. Soil water is measured in all legume plots and in the fallow plots at legume planting in April, at each legume-growth-termination event, at wheat planting and at wheat harvest to determine water used by the legume and the wheat. Above ground N and total legume biomass is determined at each termination date. Soil inorganic N is measured in each plot at each termination date in the top 2 feet of soil and at wheat planting time to monitor changes in available N. Following the legume fallow phase, wheat is planted and harvested using standard BMP's for dryland winter wheat.

RESULTS: In 1994 at Akron, CO, the total precipitation received between January and the end of June was 4.1 inches. In 1995, 15.1 inch of precipitation was received for the same period. Biomass measured in July, 1995 was nearly double that measured in 1994 (compare 2400 lbs/acre on July 12, 1995 with 1300 lb/acre on July 8, 1994). In both years we measured more biomass and biomass N (116 lb/a total above ground biomass N) with Austrian-winter peas than with the other legumes. For the Austrian winter peas we calculated a water-use efficiency of 335 lbs of dry matter per inch of water used on June 13, 1994. The 335 lbs of biomass, contained 11.6 lb of N. In other words, 11.6 lbs of N was fixed or taken up by the legume for each inch of water use. The legumes used 5 inches of water (in addition to that amount lost in summer fallow) to produce 2400 lbs of dry matter. That 5 inches of water use has the potential of producing 25-30 bushels of wheat. We measured a 5 bu/acre reduction in wheat yield even at the earliest legume termination date of May 31. At current fertilizer costs legume N is too expensive to be considered a viable alternative. If one considers the additional value of the forage at a market price of $80/ton grown during fallow then the forage produced by the legumes (plus the reduced wheat yield) in this system is almost economically comparable to winter wheat fallow.

FUTURE PLANS: We would like to continue this study for a minimum of 6 years. We believe at least three complete cycles of the system are needed to make a fair evaluation of potential changes in soil organic matter and mineralizable N. Much of the legume and wheat production information in this system will be ready for publication after this coming summer.

BASE TEMPERATURE AND GROWING DEGREE HOURS REQUIRED FOR CANOLA EMERGENCE

Merle F. Vigil and R. L. Anderson

PROBLEM: Canola is a potential oilseed crop for the Central Great Plains. Since canola is planted when soil temperatures are below the optimum, farmers occasionally have stand losses from seed rotting in cold soil. Knowledge of the growing-degree hours (GDH) required for emergence of canola planted at different planting depths can help producers decide when and how deep to plant the crop.

APPROACH: We studied the emergence of 3 spring canolas: (Alto, Tobin, and Global) and 2 winter varieties (Glacier, Crystal). Constant temperature incubators were used to evaluate emergence over time. Incubation temperatures were : 0, 2, 4, 8, 12, and 16°C (32, 39, 46, 54, and 61°F). These temperatures correspond to early spring temperatures in the central Great Plains. All varieties were planted 1 cm deep in pots in a Weld silt loam. Two varieties were also planted 2, 2.5, 3, and 4 cm deep to investigate planting depth by temperature interactions. Soil water content was held constant at 0.18 g g-1. The number of seeds emerged in each pot were counted on a daily basis and twice daily during the rapid emergence phase at 12, and 16°C. Emergence and accumulated heat units (GDH) were determined until emergence was complete for each pot. The experiment was replicated 4 times. We used segmented-nonlinear-regression to determine GDH required for initial emergence. Base temperature (the minimum temperature at which canola will emerge) was estimated using simple-linear regression.

RESULTS: Canola emerged at temperatures as low as 2°C (36°F) with a calculated base temperature between 0.4 and 1.2°C (33 and 34°F). Initial emergence began between 1560 and 1940 GDH for spring canolas and between 1600 and 2800 for winter canola. A comparison of emergence data in this study with accumulated heat units and the long-term-heat accumulation in the spring in the central Great Plains indicates that spring canola should be planted when average soil temperatures in the top 4-cm of soil are near 4 °C (39 °F). In an average year, in Washington county Colorado, these temperatures can be found in the surface soil the last week of March. After that time the soil becomes progressively warmer. The percent emergence of canola planted 1-cm deep was not significantly different from that planted 4-cm deep at temperatures greater than 4°C at near optimal soil water contents. The soil depth information indicates that higher seeding rates early in the spring may be required to offset potential stand losses from canola planted too early when soils are cold. A modified Michaelis-Menton model could describe 99% of the variability in emergence as a function of accumulated heat units for the varieties used in this study.

FUTURE PLANS: This study is in manuscript form and has been submitted to Crop Science. Our research in this area is complete and no further canola emergence research is planned.

NITROGEN MINERALIZATION AND CROP RESPONSE TO MUNICIPAL SEWAGE SLUDGE

Merle F. Vigil and Rudy Bowman

PROBLEM: The disposal of municipal sewage sludge from large population centers is a national environmental concern. These materials, loaded with organic and inorganic nutrients, can be recycled in crop production systems as fertilizer and soil quality amendments. If managed properly, they become a resource instead of a waste product. However, the quantification of suitable rates of application, methods of application, crop response, and changes in soils after repeated application are data needed to adequately develop best management practices (BMP's) for these organic materials.

APPROACH: The objectives of these experiments are to determine: (i) the amounts and rates of decomposition of organic amendments (manures and sewage sludge) in farm soils, (i) how much value they may have as fertilizer and as soil quality amendments for crop production. Field studies are used to compare the N response of dryland crops (canola in 1996) to 4 tons of dry granulated sewage sludge with the N response to 30 , 60, and 90 lb/ac of N as ammonium nitrate. In 1996 we will compare 3 rates of dry granulated sewage sludge with 3 comparable rates of ammonium nitrate in 4-rep randomized complete block field experiments and as a soil quality amendment.

Lab studies are being conducted to evaluate N and C mineralization amounts from these materials in Central Great Plains soils and to developed first-order-decay-rate constants for dry-granulated sewage sludge. Simultaneously we are evaluating computer models for their ability to predict how these amendments will impact soil nutrient availability and crop uptake.

RESULTS: We measured a canola grain yield response to 4 tons/acre of dry-granulated sewage sludge (1100 lbs/acre) that was just slightly less than that found with 90 lb/acre commercial N (1490 lb/acre). Chemical fertilizer (ammonium nitrate) and sludge were top-dressed just after emergence in April of 1995. Because the sludge contained 5.3% N this field study suggests that during the growing season of early spring crops only 21% of the sludge N applied at planting will be available for crop uptake during the season.

We estimate from our lab studies that dry-granulated sewage sludge (5.3% N) applied at rates of 1.5 ton and 9 ton per acre will release (through microbial decomposition) 45 and 270 lbs of N in a given season under irrigated conditions in our region (about 28% of the total N applied). Under dryland conditions we may only see 34 to 200 lbs of N released for 1,5 and 9 tons of dry sludge. Less sludge N mineralization is expected on dryland because dryland soils are less biologically active then moist irrigated soils.

FUTURE PLANS: Sludge and manure studies are only in the beginning phases of research and will be continued. We are evaluating these products as an amendments to reclaim eroded soils.

WHEAT RESIDUE DECOMPOSITION AS EFFECTED BY HERBICIDE AND UAN APPLICATION UNDER FIELD CONDITIONS

Merle F. Vigil, R.L. Anderson and Rudy Bowman

PROBLEM: The amount and type of crop residues left on the soil after harvest affects soil erosion. For farmers to be in conservation compliance they must have, in accordance with their farm plan, a specified amount of residue cover at planting. Unfortunately, crop residues decompose after harvest and become less resilient during the non-cropped part of the season. These partially decomposed residues can then be wind blown and lost in the same manner as soil. Minimal quantitative information exists on the durability of standing crop residues as affected by the applications of herbicide and N fertilizer.

APPROACH: After wheat harvest (August of 1993, and 1994) 45 by 16 foot field plots were established with the following treatments where all rates are active ingredient/acre: 1) 0.5 lb Command + 0.5 lb Atrazine applied mid-August. 2) 0.5 lb Glyphosate + 0.25 lb Dicamba (Banvel) applications as needed. 3) 0.5 lb Paraquat + 1.0 lb Atrazine applied mid-August. 4) 0.5 lb Paraquat + 0.25 lb 2,4 D as needed. 5) no treatment, hand weeded (plastic spread over top of hand weeded area). 0.5 lb Command + 0.5 lb Atrazine. 6) tillage, no herbicide 2-3 times as needed (sweep plow with mulch treaders). Superimposed onto these treatments are three N regimes: no N applied, 30 lb N as UAN, and 60 lb N as UAN. All plots are replicated 3 times and arranged in a randomized complete block design. The following measurements are being taken. 1) Photo-documentation of plots was done after plots were established, after herbicide application, and then periodically as needed to document differences or lack of differences due to treatments. 2) The number of standing wheat stems is counted in select areas of each plot once a month during the no-snow months (depending on snow depth). Measurements continue until planting of the next wheat crop.

FINDINGS: No increase in standing stem loss due to herbicide has been measured as of January 5, 1995. Initially a color change could be observed after herbicides and N solutions were applied. With time, color differences faded. We have lost 100% of the standing stems originally counted in August of 1993 and 9 to 23 % of those counted in 1994. The loss is primarily driven by the number of days with high winds, and optimal temperature and moisture for microbial activity. Herbicide treatments do not appear to have any direct effects on stem loss. Whereas, some indirect effects have been observed. We measured greater stem loss at the 60 lb N rate as compared to the 0 or 30 lb N rate. We found that the accumulated wind run was more highly correlated to the incremental loss of standing stem loss than either temperature or precipitation.

FUTURE PLANS: The experiment established in 1993 is complete with 100% standing stem loss. The second experiment established in 1994 will be continued until we have achieved 100% loss.

NITROGEN RESPONSE OF TRITICALE IN A DRYLAND N ANNUAL CROPPING STUDY

Merle F. Vigil, Curt Ruele, and Ardell Halvorson

PROBLEM: Improved conservation tillage has increased annual soil water storage. This has enabled the use of annual cropping for some soils of the central Great Plains. Annual cropping entails greater biomass production which increases the need for more intensive N fertilizer management. This study is designed to evaluate long term changes in soil C and N under annually cropped dryland conditions under different N fertility. Short term, the study allows for the estimation of N use efficiency and fertilizer N requirements of various dryland crops.

APPROACH: This is the 12th year the experiment has been conducted, where under dryland conditions, the site has been cropped rather successfully with no fallow on a Weld silt loam soil. The cropping history has generally been in a barley-corn rotation until 1992 when oats for hay replaced spring barley. Winter wheat was grown in 1988 to replace a hailed out corn crop in 1987. Only one other year of the 12 year study has been a failure: in 1990 poor stand and aphids limited barley yields to 21 bu/acre. The experiment is a 4-rep randomized complete block where the only treatment is N fertilizer rates of 0, 20, 40, 60, 80 or 120 lbN/acre. The study is managed with no-till to conserve water and weed control has been through the use of contact and residual herbicides. Phosphorous (P) nutrition has not been limiting but low rates of P have been applied with the seed at planting or as broadcast treatments. Soil profile water and nitrates are monitored on an annual basis to determine N balance and water use efficiency.

RESULTS: In general, over the years the optimum N rate for small grains has been between 40 and 60 lbs N /acre. For corn it has been between 60 and 80 lbs of N/acre. However, a buildup of excess nitrate-N can be found in the soil of plots fertilized at 80 lbs or more. This buildup is in excess of 300 lb/acre in plots fertilized at 120 lb N/acre. These results suggest that with this soil (under dryland conditions) annual fertilizer N rates can be excessive after 80lb/acre on a long term basis.

Oat hay yields in 1995 were about 1.3 ton/acre at the optimum N rate of 60 lb/acre. On Oct 20, 1994, triticale was planted and on July 5th total above ground biomass yields were collected. At the 80 lb N rate 5.5 ton/acre of total dry matter was harvested. This plant tissue averaged 16% crude protein at the time of harvest. The crude protein yield on these plots was about 1 ton/acre which rivals the total protein yield of a 200 bushel irrigated corn crop and a 4.5 ton alfalfa crop. Earlier on June 1, we harvested 2.4 tons of hay which averaged better than 18% crude protein at the 80 lb N rate.

FUTURE PLANS: We will continue this experiment for another 3 years to evaluate long term changes in soils under high N management and to determine changes in soil C and N with high productivity. We are considering the use of ^{15}N to evaluate fertilizer N recovery.

NITROGEN RESPONSE AND RESIDUE MANAGEMENT OF SUNFLOWERS IN A DRYLAND ROTATION

Merle F. Vigil, David Nielsen, Rob Aiken and Rudy Bowman

PROBLEM: The current worldwide demand for edible oils has improved and somewhat stabilized the profitability of sunflowers in the Central Great Plains. However, knowledge of options for sunflower residue management and the fertilizer N response of this crop in the region is limited. Maintaining sunflower residues on the soil surface during fallow protects the soil from erosion, increases water infiltration and maximizes soil water storage. The objectives of these studies are: (i) to compare the loss of sunflower residues under no-till and reduce-till managed summer fallow, and (ii) to evaluate the nitrogen (N) use efficiency and plant derived N from fertilizer of this crop in a wheat-millet-sunflower-fallow rotation.

APPROACH: *In the sunflower residue study*: The disappearance of sunflower residue from sunflowers cut at two stalk heights (20 and 27 inches) were compared under no-till and reduce-till managed fallow in a 4-rep randomized complete block designed experiment. Weeds were controlled using a sweep-plow in the reduce-till plots. Glyphosate (Roundup) was used to control weeds in no-till plots. Standing-stem counts, percent-residue cover (line transect method) and surface-residue mass were measured during summer fallow on a monthly basis.

In the N fertilizer-rotation study: Sunflower were planted and fertilized in a randomized split-plot 4-rep experiment. Main plots consist of rotation crop/phase (sunflowers, proso-millet, wheat or fallow) and sub-plots are fertilizer N rates of 0, 30, 60, or 90 lbN/acre. All phases of the rotation appear every year in each replication. Soil water and inorganic N are monitored at planting and after harvest to assess water and N use efficiency and to evaluate deep N and water extraction by sunflowers. Individual plots are 60 ft by 240 ft in size. Deep placed ^{15}N labeled N will be used to evaluate fertilizer N recovery with soil depth.

RESULTS: Taller sunflowers (27 inch) fell over sooner then shorter sunflowers (20 inch). No-till resulted in 2700 lbs of residue mass per acre on the soil surface at wheat planting time and maintained greater then 34% residue cover during summer fallow. Sweep-plow managed fallow contained 1900 lbs of sunflower residue per acre at wheat planting time, but only 20% residue cover as measured by the line transect method. Sunflower N response was optimal at around 30 lb of N/acre. Residual soil N eliminated much of a response this first year of the study. Much of the data collected in the N-response-rotation study is still being analyzed.

FUTURE PLANS: For both studies only one year of data has been collected. At least one more year of data is needed for the sunflower residue. The N response of sunflowers in a rotation requires at least 2 complete cycles of the rotation for long term conclusions. However much of the N response, and fertilizer N recovery information will be available after the first 3 years of the study.

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GREAT PLAINS SYSTEMS RESEARCH UNIT

Lajpat R. Ahuja, Research Leader
Federal Building
301 S. Howes, Room 353
P. O. Box E
Fort Collins, CO 80522
TEL: (970) 490-8300
FAX: (970) 490-8310

FTS2000: a03rlgpsr@attmail.com
INTERNET: ahuja@gpsr.colostate.edu

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CRIS PROJECTS

5402-13610-003-00D	Impacts of Climate and Environmental Change on Agricultural Resources and Watershed Processes
5402-13660-002-00D	Conjunctive Studies of Surface, Vadose, and Groundwater Quality
5402-13660-003-00D	Model Root Zone Water and Chemical Dynamics
5402-61660-004-00D	Development of Improved Cropping System Models and Technology for Sustainable Production
5402-61660-005-00D	Development of Improved System Models and Technology for Susteained Rangeland Production
5402-66000-001-00D	Development of a Decision Support System for Farmers and Ranchers in the Great Plains
5402-61000-002-00D	Global Change Research, Modeling, and Database Management, with emphasis on Terrestrial Systems

MISSION STATEMENT

Help develop and implement sustainable and adaptive agricultural systems by: (1) synthesizing, quantifying, evaluating, and enhancing knowledge of processes; (2) developing integrated models of agricultural systems; and (3) providing technology packages to agricltural communities and action agencies.

Comprehensive efforts are directed towards: (1) integrated analysis of production, water quality, environmental change, and sustainable on-farm/regional management systems; and (2) creation of decision support systems for on-farm management.

TECHNOLOGY TRANSFER - 1995

Great Plains Systems Research Unit

1. The alpha version of GPFARM decision support system has been nearly accomplished, with a package of main science modules, parts of the user interface, and remotely-sensed maps of two cooperators' farms for testing. Feedback from a core user group is being obtained.

2. Cooperative evaluation of the RZWQM with MSEA group has been completed. The plan is to publish a package of seven papers in Agron. J. The model was enhanced to simulate long-term evaluation of BMP scenarios.

3. Worked with the national NRCS NLEAP team to develop a NRCS NLEAP workbook using regional cropping scenarios across the US and with demonstration projects in Colorado (2) and Wisconsin (1) on application of NLEAP to water quality issues. NLEAP science modules were incorporated into the national extension model, PLANETOR. A CRADA was developed with J.R. Simplot for the incorporation of NLEAP technology into a Simplot software package for fertilizer recommendations. NLEAP training was conducted for scientists and private industry.

4. Working with the Colorado NRCS, the SHOOTGRO model was used to simulate biomass production of winter wheat for different sites in eastern Colorado for their RCA compliance program. The results have been distributed to Colorado Field Offices for adoption and a manuscript accepted by the Journal of Soil and Water Conservation. Discussions have been initiated to incorporate the work in the NRCS RUSLE software, and to apply the approach to Kansas, Nebraska, and other sites in Colorado.

5. SPUR 2 is being used by the country studies team (EPA, DOE, and others) for climate change research on rangelands. A workshop was conducted to teach scientists from 10 countries how to use SPUR2 to determine manager next policies in light of climate change.

6. GWM/WEEDCAM was demonstrated to two groups of consultants, farmers, extension agents, and commercial applicators.

7. Helped coordinate and served as facilitator at 1995 Forest Service workshop, applying and demonstrating Groupware technology. Created a hyper-linked Workshop Summary for the Forest Service national home page on the World Wide Web.

8. Coordinated USDA review of 1995 Intergovernmental Panel on Climate Change Scientific Assessment, in USDA Global Change Program Office, Washington, DC.
Designed and delivered invited workshop for Congressional Research Service, Washington, DC.

REMOTE SENSING AND INTEGRATION OF SOIL WATER AND ENERGY TRANSFER PROCESSES OVER LARGE AREAS

L.R. Ahuja, K.E. Johnsen, T. Engman[1], and N. Matakali[1]

PROBLEM: The simultaneous description of moisture and heat energy exchange at the soil surface is an important aspect of the total mass and energy balance in a watershed. Knowledge of the physics of the system, field measurements of the processes of exchange, together with the factors involved with scaling from point to large basins, is required for proper simulation.

APPROACH: This project has two objectives: (1) Investigate the potential of obtaining subsurface soil hydraulic properties from remote-sensed surface soil moisture changes and available soil map information using the Root Zone Water Quality Model (RZWQM); (2) Evaluate the convergence scaling theory for integrating water and energy fluxes over large areas.
For Objective 1, the remote-sensed and gravimetrically measured surface moisture data from several parts of the Little Wachita watershed in 1992 will be utilized. First estimates of subsurface soil hydraulic parameters will be obtained from available soil survey data on texture and bulk density using the SOILPROP subroutine of RZWQM. These estimates will then be refined by calibrating the RZWQM-simulated values of surface moisture changes against the measured values. The final calibrated estimates will be validated against field measurements for selected cases. For Objective 2, the RZWQM model will be linked to GIS technology and the databases (soils, topography, climate, channels) for the Little Wachita Watershed. Starting with uniform initial conditions and assuming uniform weather conditions, the model will be run for each pixel to generate data on water and heat fluxes. The scaling of these fluxes with respect to scaling of soil hydraulic parameters will then be explored.

RESULTS: The soil hydraulic properties of water retention and hydraulic conductivity as functions of soil water content or potential for several different horizons have been obtained from surface water content measurements for 15 sites of the Little Wachita watershed. The calibration fits looked good in all cases.

FUTURE PLANS: The above calibration method will be validated against theoretical surface water content data generated by numerical solutions for three different soil types. In addition, the method will be tested in the field at five (out of 15) selected locations by measuring hydraulic properties of the subsurface horizons and soil surface water content changes after a thorough wetting. Later, the work outlined above for objective 2 will be undertaken.

[1] NASA-GSFC, Hydrologic Science Branch, Greenbelt, MD

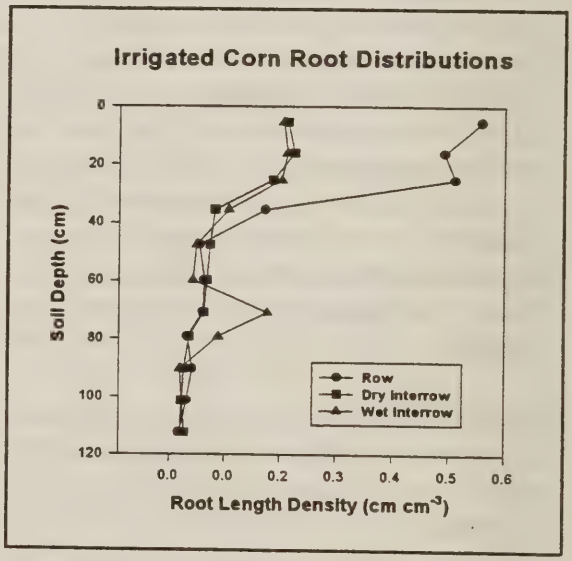
SPATIAL DISTRIBUTION OF FURROW-IRRIGATED CORN ROOTS

R.M. Aiken, H.J. Farahani, W.C. Bausch, J.D. Hanson and L.R. Ahuja

PROBLEM: Knowledge of water and solute flux in rooted soil is constrained by uncertainties associated with root systems. The dynamic spatial distributions of root networks modify water and solute uptake patterns which can limit plant growth processes. Accurate simulation of root effects on soil and water flux and plant growth requires knowledge of root spatial dynamics.

APPROACH: We sampled row and interrow root distributions under an irrigated corn crop at four-leaf and anthesis growth stages. Manual separation of washed roots distinguished live (white) from dead (discolored) root segments. Image analysis techniques provided subsequent measure of root length density for five root diameter classes. The Root Zone Water Quality Model (RZWQM) provided simulation of canopy and root growth and development.

RESULTS: Most roots, at anthesis, occurred in the upper 40 cm soil layers at this furrow-irrigated site. Root length densities under dry and wet furrows were similar, and approximately 40% of that under crop row. At greater depth, root length densities were similar at all positions though spatial variability was indicated under wet furrows at 70 and 80 cm depths. The dominant root diameter classes ranged from 140 to 400 μm.



FUTURE PLANS: Dynamic root distributions, simulated by RZWQM, will be compared with field observations to determine predictive accuracy and model sensitivity. A manuscript reporting these results will be submitted for publication, subject to peer-review.

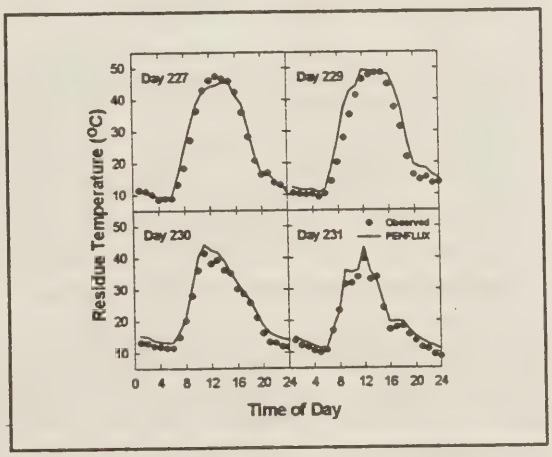
SIMULATING YEAR-ROUND ENERGY AND WATER FLUX UNDER CROP RESIDUES

R.M. Aiken, G.N. Flerchinger[1], K.L. Johnsen, H.J. Farahani, L.R. Ahuja, D.C. Nielsen, and K.W. Rojas

PROBLEM: Residue architecture (standing height, percentage soil cover, reflectance, etc.) modifies soil warming and water conservation by shading and 'insulating' surface soil layers. Decay of residue, dependant upon temperature and water conditions, results in seasonal changes in residue architecture, with impacts on soil temperature and water status. Winter freeze-thaw conditions complicate analysis of residue effects on soil and water management. Accurate simulation of year-round energy and water exchange processes provide analytic tools guiding residue management.

APPROACH: Crop residue impacts on energy and water exchange are quantified by PENFLUX, a soil-residue energy balance module providing boundary conditions for soil heat and potential evaporation modules of the Root Zone Water Quality Model (RZWQM). Year-round simulation of residue impacts by RZWQM is provided by incorporating energy exchange modules of SHAW, a process-level simulation model including freeze-thaw thermal dynamics of soil. Predictive accuracy of energy balance simulation is determined by comparing simulation results with micrometeorological observations acquired under dryland wheat, corn, sunflower and millet residues.

RESULTS: We refined near-surface exchange coefficients in the PENFLUX module, enhancing predictive accuracy, depicted in the adjacent figure. A manuscript describing the PENFLUX module is submitted for publication, subject to peer-review. We also completed merger of SHAW energy exchange processes into a beta test version of RZWQM, verifying simulation consistency with previous RZWQM results for a MSEA water quality demonstration site.



FUTURE PLANS: The PENFLUX module requires a companion residue water balance, under development, for accurate simulation of thermal conditions following precipitation or dew accumulation events. Further evaluation of SHAW and PENFLUX modules will utilize archived data acquired at Pullman, WA, Fort Collins, CO, and Akron, CO representing a range of residue architectures in semi-arid climates. Manuscripts reporting the predictive accuracy of these modules under winter and non-freezing conditions are in preparation.

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[1] ARS Northwest Watershed Research Center, Boise, ID.

DEVELOPMENT OF A DECISION SUPPORT SYSTEM FOR FARMERS AND RANCHERS IN THE GREAT PLAINS

GPFARM Development Team: J. Ascough II, M. Shaffer, J. Hanson, G. McMaster, L. Wiles, B. Vandenberg, P. Bartling, D. Edmunds, L. Deer-Ascough, H. Yin, and L.R. Ahuja

PROBLEM: Maintenance of sustainable agriculture in the Great Plains is a complex problem requiring consideration of a range of interrelated factors, processes, and institutions. Past management practices and Federal programs have created special environmental, managerial, economic, and political needs that must be addressed. The ability to analyze and modify farm and ranch management practices to take advantage of the changing global economy; new cropping, pest management, and tillage systems; and future legislation while protecting environmental resources, will determine whether an agricultural enterprise system survives or perishes.

APPROACH: The Great Plains Framework for Agricultural Resource Management (GPFARM) decision support system (DSS) is being developed to analyze and develop strategic 1-10+ year management plans. GPFARM will provide an operational framework for farm/ranch decision support from which alternative agricultural strategies can be developed and tested. Strong emphasis will be placed on simultaneous analysis of profitability and environmental protection through the development of an economic budgeting package and an object-oriented framework integrating the interface, science modules, and databases. Future versions of GPFARM will include components for GIS, multiple criteria decision analysis, and risk analysis.

RESULTS: GPFARM system components developed include a 32-bit Microsoft Windows (Win 95) interface, an object-oriented C++/FORTRAN framework for integrating science modules, a detailed whole-farm economic budgeting package, and customized Microsoft Access relational databases. Science modules were adapted from existing models, or in the case of weed management and water solute transport, new modules were developed. Efforts are underway to investigate existing NRCS databases and to port those which are required by GPFARM into Microsoft Access. Remotely-sensed spatial data is being studied and analyzed, and base maps of two cooperators farms have been produced from aerial photography and geo-rectified. A user requirements survey of computer use in the Great Plains was completed and analyzed. An evaluation team has been created and is being asked to help guide GPFARM development efforts through detailed testing and evaluation.

FUTURE PLANS: Graphical user interface (GUI) screen design will be modified and enhanced based upon evaluation results from intended customers. Development of the databases and science modules will continue. Object-oriented design techniques for merging of the science modules, databases, and interface into an integrated system framework will be fully implemented. An inclusive project management structure that includes a detailed task list, work breakdown structure, resource analysis, and quality control measures will continue to evolve and will be used to chart expected development progress of GPFARM. Based on project management timelines, a beta test version of GPFARM will be ready in 1996. The beta version will be tested on cooperators farms and improved as needed. Multiattribute decision making will be used as an additional evaluation tool as soon as the beta version of GPFARM is ready for release.

MINIMIZING CHEMICAL LEACHING BY ALTERNATE FURROW IRRIGATION AND FERTILIZER BANDS

J. G. Benjamin, L. R. Ahuja, G. Butters[1], L. Porter, and H. Duke

PROBLEM: High nitrate levels in groundwater in the Great Plains has been attributed to nitrogen fertilizer applications on cropland. Alternative soil management techniques must be found to allow the use of nitrogen fertilizers on crop land and yet minimize adverse environmental effects.

APPROACH: An irrigation-nitrogen placement experiment for irrigated corn production was established in 1994 at ARDEC (Agricultural Research, Demonstration, and Education Center) at Ft. Collins, Colorado. Two irrigation water placements, alternate furrow irrigation (AF) and every furrow irrigation (EF), and two nitrogen placements, in-furrow (IF) and in-row (IR), were tested to determine the plant use of the nitrogen fertilizer and nitrate leaching in the soil. Labeled ^{15}N fertilizer was used to differentiate fertilizer nitrogen from naturally occurring nitrogen in the plant and the soil. Corn physiological development, biomass, total nitrogen uptake, fertilizer nitrogen uptake, corn yield and yield components were measured during the growing season to determine the effects of irrigation water placement on crop growth and the availability of nitrogen to the plant with the various placement options. Soil hydraulic properties, water contents before and after irrigation, and fertilizer nitrogen distribution at the end of the growing season were measured to determine fertilizer leaching.

RESULTS: Analysis of first year data from the experiment showed that: 1. Corn development, biomass, and yield were as good with AF irrigation as with EF irrigation; 2. N fertilizer uptake was greater for the IR than the IF placement early in the growing season but both were similar by the end of the growing season; 3. Total N uptake for the AF-IF treatment was about 85% of the other treatments and fertilizer N uptake for the AF-IF treatment was about 50% of the other treatments; 4. Total N uptake and fertilizer N uptake were similar among the EF-IR placement, EF-IF placement, and AF-IR placement by the end of the growing season; and 5. Fertilizer N leached to > 1 m in the EF-IF treatment but < 0.5 m in the AF-FP treatment.

FUTURE PLANS: Data analysis from the 1995 study will be completed. The experiment will be continued in 1996 with plans to include the collection of additional data to determine soil environmental effects on corn root distributions. A combined analysis of the two year's data will be conducted to determine overall leaching patterns of fertilizer nitrate and plant uptake. Modelling studies will be conducted to expand the findings from the field study to other irrigation rates and placements.

[1] CSU, Dept. of Soil & Crop Sciences

WATER AND BROMINE MOVEMENT INTO AN ARTIFICIAL BURIED MACROPORE

J. G. Benjamin, L. R. Ahuja, and H. R. Havis

PROBLEM: Soil macropores formed by root channels and soil biota such as earthworms have been shown to be conduits for a rapid or preferential transport of water and chemicals from the soil surface to underlying soil layers. Field observations suggest that macropores disrupted by tillage may continue to act as preferential flow paths for water and chemicals in some cases but not in others. The objective of this study was to investigate conditions under which a buried macropore might act as a preferential flow path.

APPROACH: A laboratory study was conducted to induce macropore flow in a buried artificial macropore. Soil columns 152 mm in diameter by 300 mm long were constructed from Plexiglas tubing and packed with either a homogeneous soil and or a layered soil. A macropore was created in the center of each column using a 3-mm diameter pointed metal rod inserted through the bottom of a packed column until it reached 70 mm from the top for the uniform system and 75 mm from the top, at the soil-mixture interface, of the layered system. Strontium bromide was used as a tracer and simulated rainfall was used to initiate water and chemical flow. A modelling study was conducted to replicate the laboratory study and also to investigate several other conditions under which flow could enter such a buried macropore.

RESULTS: In the homogeneous soil, neither the laboratory study nor the model predictions indicated flow into a buried macropore under the experimental conditions. Model simulations predicted no flow entering the macropore in a uniform soil even with long rainfall or ponded surface conditions. For the layered system, flow into the macropore was predicted from model simulations under the experimental conditions, but no macropore flow was measured out of the macropore bottom from the laboratory columns, indicating possible reabsorption of water and Br^- along the wall of the macropore. All simulations for the layered system predicted macropore flow. The results show that the buried macropore can contribute to preferential flow and chemical transport in a layered soil, but not in a uniform soil. A thin plow pan existing in a uniform soil profile induces macropore flow as much as a lower-conductivity subsoil horizon. Maximum macropore flow and more chemical movement occurred under ponded water conditions than with rainfall. A higher rainfall intensity and a lower hydraulic conductivity of the subsoil would enhance macropore flow. Most natural soils are either layered or have a tillage pan. These findings illustrate the need to document the location of soil horizons and the depth of tillage-induced or naturally-occurring restricting layers for field studies of flow in disrupted macropores.

FUTURE PLANS: The results will be used for future modeling efforts to better describe preferential flow paths in agricultural fields. Water flow and infiltration models may need to be modified to account for the tillage system used for crop production.

INSTALLATION OF THE ROOT ZONE WATER QUALITY MODEL INTO THE MODULAR MODELING SYSTEM (MMS)

C. Bierbaum, K. Rojas, and L.R. Ahuja

PROBLEM: MMS is a software developed by the USGS for the purpose of providing a common framework for the development and testing of process based modules and to facilitate integration of these process modules into operational physical models. By providing a consistent framework for model development and application, it is hoped that the installation of the Root Zone Model in MMS will enhance the integration of related ARS process modules into the model. In addition, the graphical interfaces supported in MMS assist users in parametetrization of model components and the visualization of model output. It is hoped that this installation will demonstrate the efficiency of implementing research models within a common framework and provide a tool to focus multidisciplinary research efforts.

APPROACH: Define distinct process modules within in the Root Zone Model which serve as the basic building blocks for the overall combined model structure in MMS. When these modules do not satisfy the required MMS coding structure, rewrite the module source code while maintaining the same functionality and capabilities as the unmodified version of RZWQM. Within each of the identified process modules, define a consistent naming convention for that module's input parametetrization variables and output display variables. This convention should produce a concise name which is consistent with current scientific nomenclature and provides the user with a clear understanding of the variables context within the associated process module.

RESULTS: Version 3.0 of the Root Zone Water Quality Model has been implemented into the MMS software. This implementation is an initial test version which will require some additional restructuring of the modules and further instructional documentation to achieve the expressed goals as outlined above. However, this initial work has demonstrated that efficient incorporation of process modules can be enhanced within the MMS system; as two process modules from the USGS-Precipitation Runoff Modeling System have been integrated as modules into the Root Zone Model.

FUTURE PLANS: Further segregation of the current modules will help promote interaction with RZWQM at a more basic algorithmic level. With this additional segregation, it is felt that the MMS platform will be a valuable tool for efficient installation of new process modules into RZWQM, and that this platform will also assist the Agricultural Research Service in examining the potential of MMS as a common software for all ARS models. In addition, a more clearly defined variable naming structure and additional on-line module documentation, will provide users with a more complete understanding of variable/process association and model capabilities. Finally, a more powerful graphical post-processing software will further assist users in the visualization and assessment of modeling results.

ENHANCEMENT AND REFINEMENT OF NLEAP TO MEET USER NEEDS

M.K. Brodahl, M.J. Shaffer, P.N.S. Bartling, and S. Aschmann[1]

PROBLEM: The interest in and use of NLEAP has expanded within State and Federal agencies, within government agencies of other countries, and with private consultants. With this increased interest, necessary program upgrades and enhancements have been identified as well as a need to broaden the application capabilities of the program. In addition, this increased use and interest in the program is making it apparent that distribution, marketing, maintenance, and support requires more resources than the developers alone can provide. Therefore, we must explore additional strategies for effectively transferring our product to the customer.

APPROACH: Re-programming is being done in object-oriented design using C++. This will facilitate the use of NLEAP technology in other related software applications. We will first re-program the simulation portions of NLEAP with the intent that this will address the immediate need of re-using this technology in other software applications being developed by the ARS. As we upgrade the simulation portions, we will enhance the crop handling and crop rotation simulations, add a more flexible soil layering, add simple irrigation scheduling, and add the capabilities for estimating fertilizer recommendations for amount and time of application based on state recommendations. Once this is accomplished, we will re-work components of the current user interface to facilitate movement to a windows interface, expand the program for international use (metric units), expand the program for GIS applications, improve data I/O and file handling, and include program capabilities for facilitating the user configuration of the program. Any re-design of the program will take into account how the user interacts with the software.

RESULTS: Enhanced NLEAP model treatment of manures in a one-year and multi-year simulations and improved treatment of crop rotations have been developed and distributed to graduate students, ARS researchers, and NRCS individuals for testing. The NLEAP nutrient technology has been re-programmed to work within the framework of GPFARM.

Work continues on the upgrading, expansion and redesign of the NLEAP software using object-oriented programing in C++. Programing efforts this past year have been directed to the simulation portion of the model. An object oriented program structure has been designed for the NLEAP simulation system and continues to be improved as programing progresses and as experience in C++ and object oriented programming is gained.

FUTURE PLANS: Complete the re-programing of the NLEAP simulation in C++ and begin re-programing of the user interface in Visual C++. Provide programming and technical support for our CRADA with J.R. Simplot Company. We will continue to search for a solution to the problem of software transfer to various customers.

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[1]NRCS, Western National Tech. Center, Portland, OR.

GLOBAL CHANGE RESEARCH IN TERRA PROJECT

Donn G. DeCoursey

PROBLEM: Global climate change is a phenomena receiving much attention because the implications or effects of change are so significant. The ARS has an extensive research effort directed at the agricultural implications of global climate change. The extent of this research effort has not been made available to the general public. Both the ARS plans and the status of existing research projects needs to be made available to the general public in order to get feedback and inform the public of the magnitude of the problem.

APPROACH: Over the past few years ARS has conducted several workshops to develop its research program with in the US Global Change Research Program (USGC/RP) under the Federal Coordinating Council's Committee on Earth Sciences (CES). Recently the US Global Change Research Program has been placed under the National Science and Technology Council (NSTC). The ARS research program has been restructured to fit the NSTC format and specific objectives and tasks identified. ARS scientists have also prepared brief statements describing specific projects. These descriptions of the ARS Global Change Research Program (ARS-GCRP) are to be published and made available to the general public.

RESULTS: Drafts of two documents describing the ARS-GCRP have been prepared. The first, Volume I, is entitled Global Change and Agriculture: Soil, Water, and Plant Resources. This document presents the ARS-GCRP with its research objectives and tasks, the rationale behind the ARS program, how it fits into the USGC/RP and the extent of ARS involvement. Volume I has been reviewed several times and is nearly ready for publication. Volume II, under the same title presents the status of the current ARS program. It is a compendium of reports describing current ARS projects and linking them to the objectives and tasks presented in Volume I. These reports, all in a common format, have been reviewed by their authors and combined into one report that is under review at the present time. Volume III is the plenary papers from one of the ARS planning meetings and presents ARS leadership perspectives on status and research needs in the areas of water resources, biogeochemical and ecosystems research related to global change.

INTERPRETATION: These three volumes, describing the ARS-GCRP, will present the ARS research program to the general public and at the same time aid in its coordination. ARS has extensive research programs in the areas of water resources, biogeochemical and ecosystem science and these three program areas depend upon the strengths of each other to adequately address the issues of global change. The ARS-GCRP will aid in coordination required for a strong program.

FUTURE PLANS: The three volumes describing the ARS-GCRP, two of which are in review and one is being assembled, will be published as soon as possible and made available to the general public and ARS scientists.

MODULAR MODELING SYSTEM DEVELOPMENT

Donn G. DeCoursey

PROBLEM: The ARS has developed a large number of models describing the physical, chemical and biological processes associated with resource management and agricultural production. Many of these models use the same or similar modules to describe the various processes. Agency scientists are also developing many new models that use some of the same modules incorporated in older models. A system is needed to reduce the developmental effort. This includes methods to reduce the time required to develop and link modules; to compare alternative sub-model process descriptions; link the models to data bases and GIS; and analyze the output of the model when applied to the data.

APPROACH: The USGS, under the direction of George Leavesley has developed a Modular Modeling System (MMS) that serves as platform within which to develop and link modules with their data bases in a GIS environment. The system enables model developers to develop new or incorporate old models such that they reside *on the shelf* and can be linked as desired without having to go to the detail normally required. The system also runs the assembled models on selected data sets and can provide various analyses of the results.

RESULTS: The most recent version of MMS along with a draft documentation was placed on the internet and made available to ARS scientists. Over the past year ARS provided support to improve the linkage to GIS, developed a prototype feedback system between modules and developed a library of terminology and guidelines to aid users in incorporating existing models. The final draft of the MMS User's Manual is in review and will be available from the USGS in a few months as and open file report.

INTERPRETATION: MMS provides the kind of support ARS scientists need to improve their modeling capabilities. Many hours can be saved in linking modules and in testing alternative process descriptions. The system provides opportunity to share modules; thus saving time in model development and testing. It also enables scientists to apply their models in a GIS environment for spatial applications, to view the results in both graphical and spatial displays and to analyze the results using standard statistical tools.

FUTURE PLANS: The Great Plains Systems Research Unit plans to work with the USGS and NRCS, who are also interested in the system, to improve MMS and make it available for all ARS scientists. Specifically the prototype feedback system needs more testing, the linkage to GIS needs further evaluation for applications to agricultural problems and the existing *space/time loop* within MMS needs to be reversed. A prototype approach to the reversal of the *space/time loop* has been developed be a group of German scientists. It needs to be incorporated in the existing USGS/ARS version. A workshop to coordinate this development is being planned.

HYDROLOGIC SCALING

Donn G. DeCoursey

PROBLEM: The interdependence of process descriptions on spatial and temporal scale is perhaps the most pressing and wide spread problem facing water resources and ecosystems research. At each scale, from that of a very small parcel only a square meter or less in area (used to study very small scale processes such as the movement of water and chemicals or interaction of plant roots with the soil and soil water) to very large areas the size of a river basin, different features are dominant, even within the same process description. The problems for ARS scientists are determining dominant features and processes at each scale and how to transition from the process description at one scale to that at another scale while at the same time incorporating the effects of spatial variability responsible for the highly non-linear responses of many processes.

APPROACH: A rather extensive review of the literature addressing the scaling issue has been undertaken. It includes a review of recent approaches such as numerous developments in use of the TOPMODEL to incorporate the spatial features responsible for hydrologic non-linearity; a review of simulations that show the significance of non-linearity; studies on dimensionality, representative elemental areas and multi-scaling applied to rainfall, flood peaks and other hydrologic processes. Problems of scaling and attempts to address these problems in ecosystems and atmospheric sciences related to hydrologic processes are also reviewed.

RESULTS: This review (not complete) was presented at a recent ASAE meeting and an abstract of part of the material was presented at an ARS workshop on climate and weather research. Much of the material has been updated, corrected and expanded to include the most current articles; however several papers related to cultivated and range ecosystems, and to atmospheric studies must still be completed.

INTERPRETATION: This report, when completed, will aid ARS researchers in identifying new concepts and research papers that may aid in model development. The material may provide ideas of new approaches to incorporate non-linear effects into models at a range of scales and to transition between process descriptions at different scales.

FUTURE PLANS: Reviews of the remaining papers will be completed and included in the paper. After more editing, the paper will be published in its entirety and abstracted for publication in a scientific journal.

TEMPERATURE REQUIREMENTS FOR GERMINATION OF WEED SPECIES OF EASTERN COLORADO

C. M. Dunan, L. J. Wiles, and R. H. Erskine

PROBLEM: The success of integrated weed management systems depends on understanding and predicting ecophysiological processes that regulate weed populations. Weed emergence is a crucial process governing the dynamics of populations and affecting the efficacy of management practices. Some farmers record soil temperature to predict when weeds will emerge in order to optimally schedule weed management practices. This illustrates farmers' need for tools to predict weed emergence in fields based on environmental variables. The objective of these studies was to determine the response of weed seed germination to temperature. This information will be used to develop and validate models that predict weed emergence as a function of environmental variables.

APPROACH: We studied the germination response to temperature of important weed species from Eastern Colorado in order to parameterize models of the pattern of weed emergence originally developed for Midwest conditions. Seeds were placed on a thermogradient plate in plastic boxes lined with filter paper, and were moistened with deionized water. Temperature range was 5 to 35 C for the first set of experiments. For the second set, the range was adapted to each species to better estimate cardinal temperatures for germination. Germination was recorded twice a day during a period of 14 days. Seeds were classified as germinated when the length of the radicle was at least 1 mm. Temperatures were recorded hourly. With these data we were able to estimate Germination Rate Constants for temperature (GRC_t) that are required to predict rates of recruitment from nondormant seeds for the Midwest emergence models. GRC_t's were calculated by regressing $\ln(G\% +1) = a + b*t$, where G% is the cumulative percent germination at a given temperature, t is time of incubation, and a and b are regression coefficients. The coefficient b represents the GRC_t at the given temperature.

RESULTS: The species studied were jointed goatgrass (*Aegilops cylindrica*), kochia (*Kochia scoparia*), volunteer wheat (*Triticum aestivum*) and millet (*Panicum miliaceum*), redroot pigweed (*Amaranthus retroflexus*), green foxtail (*Setaria viridis*) and sandbur (*Cenchrus incertus*). Germination of sandbur and foxtail was poor due to high dormancy or low viability. The other species showed slower germination at 5 C with a long lag period compared to higher temperatures. Calculation of GRC_t to evaluate the impact of temperature on the rate of germination showed low sensitivity and it is difficult to determine a clear response of GRC_t to temperature. This may be due to the fact that GRC_t's do not account for the lag period that occurred at low temperatures.

FUTURE PLANS: During 1996 we will finish a second set of experiments for all the species and we will start experiments to determine Germination Rate Constants for water (GRC_w) . This is another parameter of the Midwest emergence models.

EFFECT OF TILLAGE VS. NO-TILLAGE ON INFILTRATION

G.H. Dunn, G.S. McMaster, L.R. Ahuja

PROBLEM: Tillage operations, specifically moldboard plowing and discing, are known to affect soil physical and chemical properties. The change in physical properties appears to be ephemeral. Several physical properties, including infiltration and bulk density go through a continuum of values beginning at plowing and progressing through the growing season arriving back at values very similar to the starting point. The soil reconsolidation process has quantifiable beginning and ending points. The in-between processes need to be parameterized and studied because an effective understanding of the process would allow for testing changes in management that would reduce runoff and erosion.

APPROACH: Ponded- and tension- infiltration were measured on conventionally tilled and no-till plots to evaluate the effect of tillage on infiltration and macroporosity. The ponded infiltration measurements assess near-steady state conditions over a relatively large area and are influenced by soil stratification as well as pore size distribution. Tension infiltration measurements focus on infiltration in defined effective pore-size ranges and allow for quantification of macropore flow in tilled and untilled soil. Both measurements are important indicators of the effects of reconsolidation on tilled soils. In addition, published data from several sources on soil water retention as affected by tillage and reconsolidation are available. We will attempt to quantify the differences in soil water retention/suction relationship of a soil in its tilled condition vs. untilled or the final reconsolidated condition.

RESULTS: Analysis of the infiltration data is progressing and early results indicate a weak relationship between no-tillage and higher ponded infiltration. Tension infiltration also shows some weak trends especially for water flux in specific pores size ranges. Analysis of the soil water retention data is being tested to see what form of the function gives the best fit.

FUTURE PLANS: Following complete data entry we will test for statistical significance differences in infiltration and tension infiltration as affected by tillage. Mathematical analysis of the water retention data will provide information on the nature of soil reconsolidation. A field experiment will be conducted to test the empirical results of the mathematical analysis. Each research effort will result in the production of a manuscript for publication.

ASSESSMENT OF DRYLAND AND IRRIGATED CROPPING SYSTEMS IN THE GREAT PLAINS - A SYSTEMS APPROACH

H.J. Farahani, L.R. Ahuja, J.D. Hanson, G.A. Peterson, G.W. Buchleiter, N.L. Klocke, W.C. Bausch, M.J. Shaffer, K.W. Rojas, D.C. Nielson, D.G. Westfall, L.A. Sherrod

PROBLEM: The complexity of the processes in the natural environment suggests the use of a *systems approach* to enhance our understanding of agricultural systems. In this context, a systems approach comprises of a combined experimental and mathematical modelling.

APPROACH: During 1995, we completed the first phase of evaluating RZWQM where *season-long* testing of the model was of major concern. Our objective was to test the integrity of individual processes within RZWQM using seasonal data from irrigated, rainfed and dryland corn production systems in Colorado and five other midwestern states, and a level basin irrigated field in Portugal. We also continued our major RZWQM model calibration/evaluation work with the Management Systems Evaluation Area (MSEA) Project with scientists representing states within the midwestern corn belt: Iowa, Minnesota, Missouri, Nebraska, and Ohio. The interest was to compare measured with model predicted values for crop yield and the various components of the soil water and nitrogen budgets which include crop water use, percolation below the root zone, nitrogen uptake, and nitrogen leaching below the root zone in corn production systems under a wide range of management practices.

RESULTS: Findings from the MSEA Project will soon be published in the Agronomy Journal. Comparison of model output against measured data from the Colorado studies indicated that seasonal predicted values for crop water use, soil water, seepage of water and nitrate below root zone, nitrogen uptake, and grain yield/biomass production ranged from zero to 30% of measured values. Model strengths and deficiencies were identified. We feel RZWQM can be used to simulate irrigated and dryland corn growth and evaluate the effects of various management practices. The simulation model has undergone an extensive testing period to make sure all known shortcomings and problems have been eliminated. With that in mind the RZWQM project has reached a crossroads in its development lifetime. The latest version (3.2) with all its capabilities has been frozen and will be released, while development of new processes and improvement of existing processes will continue simultaneously. Some of the fundamental processes in the model require further research and refinements. Effects of tillage and reconsolidation on the temporal changes in soil hydraulic properties, of water stress on plant growth and yield, and of residue cover and architecture on energy balance are the important processes in this category.

FUTURE PLANS: Up to now, most of our efforts have concentrated on seasonal evaluations of RZWQM. For the 1996 year, we plan to expand model evaluation to simulating *long-term* cropping systems. For this, we have identified four long-term field experimental studies in eastern Colorado and western Nebraska that are each about a decade long and provide excellent measurements to meet our objective. This long-term evaluation is necessary to gauge the consistency of model behavior before assessing the impacts of alternate management practices on production and the environment.

SIMULATION MODEL SENSITIVITY ANALYSIS

V. A. Ferreira, G. Weesies[1], D. Yoder[2], G. Foster[3], and K. Renard[4]

PROBLEM: Model applications require compiling input data that describes conditions being simulated and driving factors (such as weather) for the simulation period. Users may expend considerable resources on this effort. Model sensitivity analyses provide users with information about model response relative to input variables, which guides users in determining how to allocate resources in data acquisition. Common practice is for model developers to perform a sensitivity analysis, which is often included in model documentation and used to guide user decisions on resource allocation. However, model sensitivity may vary with simulation conditions.

APPROACH: The RUSLE model, an ARS product used by the NRCS, was studied at the request of the NRCS. Hundreds of model runs were made under several different management and climate (Illinois, Kansas, and Georgia) scenarios. Input parameters tested were those which users have flexibility in evaluating. Scenarios were designed and input data were chosen by NRCS practitioners in cooperation with RUSLE developers at Tucson AZ, Oxford MS, and the University of Kentucky. Scenarios and tested parameters were chosen to demonstrate the site- and condition-specific nature of sensitivity analysis.

RESULTS: Model sensitivity was shown to vary with simulation conditions. While some parameters responded similarly under different crops, management, and climates, other parameters responded very differently. The study concluded that users should conduct individual analyses for their specific conditions.

FUTURE PLANS: The NRCS has requested an extension of the study, to report further findings (beyond the selected results presented in the publication). Results indicated also that several parameter values should be adjusted and some simulations should be rerun. This project will be continued as time and resources permit.

1 USDA-NRCS, National Soil Erosion Research Lab, West Lafayette, IN.
2 Agricultural Engineering Dept., University of Tennessee, Knoxville, TN.
3 ARS, National Sedimentation Lab, Oxford, MS.
4 ARS, Southwest Watershed Research Center, Tucson, AZ.

WEATHER CHARACTERIZATION

Virginia Ferreira

PROBLEM: Many projects include weather components which require research. Efforts at TERRA included studies in the Rocky Mountains and in the Rio Puerco watershed. The GPSR group's RZWQM and GPFARM models both require weather generators and associated input parameter sets. The Akron group is interested in weather characterization relative to Great Plains dryland farm management strategies.

APPROACH: The first step for all of the above problems is analysis of data availability, followed by accessing and analyzing the data. This process is now underway for Great Plains information; data gathered for previous TERRA (now defunct) studies will be applicable to some of the work. In cooperation with the Colorado State Climatologist office, several long-term weather data sets are being computerized. ARS data is also being analyzed for salvagability (Akron, CO in particular). Also, weather generator programs and input datasets have been acquired and are being studied for appropriateness in RZWQM.

RESULTS: Earlier work studied the correlation of daily rainfall amounts as a function of distance between gages, performed with data from the Georgia Coastal Plains Experiment Station.

An initial statistical analysis of monthly and annual total precipitation has been started on the record from Leroy, CO, formerly available only from 1948 (now on computer back to 1896).

FUTURE PLANS: The spatial-correlation work from Georgia was presented to ASAE; a manuscript is in review for publication in theTransactions. The initial Leroy analysis has been discussed with several Akron farmers. A proposed weather/plant-growth-stage scheme was also shown to them. Their enthusiasm warrants continuing this work. Future cooperative efforts with Akron and their Customer Focus Group include:

- data recovery. Akron records of wind, soil temperature, vapor pressure, solid precipitation (daily inputs and on-ground accumulations), and observer notations are being computerized for the period 1896-present. Records of short-term storm precipitation/runoff studies (from Rome Mickelson and Vic Hauser) are being evaluated for possible rescue attempt. Work on the Leroy record will also continue.
- producing monthly or seasonal precipitation maps of NE Colorado
- analyzing possible relationships among el Nino/la Nina and NE Colorado observed weather variables.

Future weather research, in cooperation with other ARS meteorologists and hydrologists, includes further analysis of time/space scaling and characterization, including Huff-type curve investigation and other disaggregation and storm-generating schemes; and weather generator improvements.

MODELING THE RAINFALL-RUNOFF PROCESS ON SEMI-ARID RANGELANDS

F. R. Fiedler, L. R. Ahuja, J. D. Hanson, G. Frasier, J. D. Salas[1], J. A. Ramirez[1]

PROBLEM: Optimization of plant and animal production from rangelands is dependent on management of a limited water supply. Grazing intensity can affect the rainfall-runoff process. Higher grazing intensities generally lead to decreased infiltration, which decreases plant and animal production. The effect of grazing intensity on small-scale spatial variability of factors that control the rainfall-runoff process is the focus of this study.

APPROACH: Four experimental plots were established on the Central Plains Experimental Range in areas representative of light and heavy grazing intensities. Rainfall-runoff simulations were performed, which included measurement of outflow hydrographs and spatially variable overland flow depths and velocities. Plot microtopography was measured with a laser profilometer. Tension infiltrometers were used to estimate hydraulic conductivities of bare and vegetated spots at each grazing intensity. Soil cores were collected and will be analyzed for bulk density, organic matter, texture, porosity, and water retention characteristics. These data have been and will be continued to be used for mathematical model development and verification.

RESULTS: Visual observations and data analysis indicate: microtopography forces flow to occur in small channels; bare spots generally correspond to microtopographic lows, and vegetated spots to highs; vegetated spots are much more hydraulically conductive than bare spots; and heavy-grazed vegetated-spot hydraulic conductivities are significantly less than light-grazed vegetated-spot hydraulic conductivities. The first three observations dictate a conceptual modeling framework. The last observation suggests that grazing primarily reduces areal infiltration by stifling plant root growth and reducing the number and connectivity of macropores. Extensive background research has been performed to identify numerical methods which will enable infiltration and overland flow to be modeled with explicit consideration of microtopographic and infiltration spatial variability. Preliminary results show that a leapfrog finite difference scheme can handle mild microtopographic and infiltration horizontal variations. A MacCormack scheme is being tested which may be better at capturing numerical instabilities associated with larger discontinuities.

FUTURE PLANS: Different numerical methods will be investigated, until the small-scale spatial variability can be adequately incorporated. Simulations will be run to extrapolate to larger scales and test the effect of grazing intensity on plant and animal production in response to water management.

[1] CSU, Dept. Of Civil Engineering.

DEVELOPING AND EVALUATING SHOOTGRO, A CEREAL GROWTH AND DEVELOPMENT MODEL

G. S. McMaster and W. W. Wilhelm[1]

PROBLEM: If we wish to better understand crop responses to management practices and environmental factors, then both physiological and developmental processes must be considered. Almost all current cereal models are fundamentally similar in that they are physiologically driven and simulate on the canopy level or higher. The general approach is that they estimate canopy light interception (based on LAI, incoming radiation, and canopy light extinction coefficients) to predict photosynthesis, and then allocate the carbon and nitrogen to general plant components such as leaves, roots, and grain. Simplistic phenological submodels provide the framework for altering physiological rates and events. Little attention is given to critical developmental processes, and most of the vast cereal developmental research conducted since 1980 is not incorporated into these models.

APPROACH: A group of ARS and university scientists are collaborating to develop a simulation model, called SHOOTGRO, that incorporates the latest research and concepts on cereal development and physiology. Many important developmental concepts are shared by cereals and other grass crops, so that one approach can be used to simulate them. A basic premise of SHOOTGRO is that if it is to accurately simulate responses to management practices, the effects of the management practices on fundamental factors such as temperature, nutrients, water, and light should be simulated first. In turn, all simulated plant processes must be modeled sufficiently to be able to respond to changes in the fundamental factors resulting from management practices.

RESULTS: The User Manual and Documentation are being written for Version 4.0 in preparation for distribution of the model. Databases for North American, English, and South African cultivars are being completed. Drs. Dale Moss (Oregon State Univ.) and Weixing Cao (Nanjing Agricultural Univ., China) visited in Sept. 1995 and are collaborating on improving the role of vernalization and photoperiod in simulating phenology.

FUTURE PLANS: SHOOTGRO is to be expanded from simulating wheat and barley to corn. Manuscripts on converting SHOOTGRO from simulating winter wheat to simulating spring wheat and barley for a variety of soils, climates, and locations are planned for this coming year. Simulating winter cereals will require better vernalization and photoperiod effects on phenology, and a winterkill submodel will be necessary for some locations. The soil submodel in SHOOTGRO is an old version from the CERES models and needs to be updated with a current version. Conversion of SHOOTGRO into modular form (MMS) is planned and linkages with RZWQM soil components is being planned. Lastly, photosynthesis and root submodels need to be added.

[1] ARS, Soil and Water Research Unit, Lincoln, NE

ESTIMATING FALL WINTER WHEAT BIOMASS PRODUCTION TO ASSIST NRCS WITH DETERMINING COMPLIANCE FOR FEDERAL PROGRAMS

Gregory S. McMaster

PROBLEM: Much of the central Great Plains is classified as highly erodible land. If wheat producers want to be involved in, and eligible for, federal programs, then they must take actions to reduce the erodibility of their land. One of the main options is to maintain a specified minimal level of residue cover, especially during periods of maximum erodibility. The NRCS considers green biomass as contributing to the total residue cover. However, an accurate method is needed to predict (with a high degree of certainty) the amount of green winter wheat biomass that will develop by December 1 in any given year. December 1 was chosen as the date after which little significant growth would occur for approximately 90 days. This prediction is needed to assess the effects that winter wheat can have in erosion control systems. A potential problem could exist for the producer by pursuing large fall biomass production and using up resources resulting in lower final grain yields.

APPROACH: The SHOOTGRO model was used to estimate the minimum biomass expected 90% of the time on 1 December and final grain yield of winter wheat for three sites in eastern Colorado (Akron, Cheyenne Wells, and Rocky Ford). Different initial conditions (e.g., planting date, planting density, soil water, and N availability) were tested at each location for the complete weather record (> 70 years). The minimum biomass simulated on 1 December 90% of the time was noted, relationships with initial conditions developed, and relationships between fall production and final grain yield examined.

RESULTS: The results have been distributed to all Colorado NRCS field offices for use in their erosion control programs through a NRCS Technical Bulletin. A manuscript reporting the results has been accepted by the *Journal of Soil and Water Conservation* for publication in 1996. The primary factors affecting fall biomass production were planting date and total water in the soil profile at planting. Secondary factors were sowing rate and water in the seedbed layer, with soil N at planting having no effect. All factors reduced in effect as planting date was delayed. There was no correlation between conditions at planting and final grain yield.

FUTURE PLANS: NRCS has requested the approach be applied to Kansas, Nebraska, and four other sites in Colorado (near Springfield, Hayden, Alamosa, and Cortez) to better handle the different wheat growing regions of the central Great Plains. NRCS would like to incorporate the results into the NRCS Revised Universal Soil Loss Equation (RUSLE) and Wind Erosion Equation (WEQ) field office programs.

DRYLAND WINTER WHEAT PRODUCTION SYSTEM RESPONSES TO SOIL MANAGEMENT PRACTICES

G.S. McMaster, R. Aiken, G. Dunn, and L.R. Ahuja

PROBLEM: No- or low-tillage practices that preserve as much residue cover as possible are being promoted for dryland wheat production systems. Most wheat development and growth studies investigated responses to temperature, water, nutrients, light, and CO_2 under conventional tillage practices. Knowledge of wheat responses to these factors under soil management alternatives is needed to guide improved management of wheat development and growth.

APPROACH: We utilize a process-based approach to investigate soil and residue management effects on wheat development and growth. First, management effects on soil temperature, water and nutrients are quantified. Second, we relate changes in these factors to effects on wheat physiology, development and yield. Third, process-based simulation models utilize the resultant knowledge to extrapolate results to other soils and climates.

Soil and residue management treatments, established in 1991, include tillage (conventional till, CT or no-till, NT) and residue cover levels (no residue, 0R; normal residue, 1R; or twice-normal residue, 2R) in factorial design. We measure daily average soil and air temperatures, weekly soil water, seasonal soil nutrient levels, and periodic heat and gas fluxes; as well as subsequent responses in wheat development and growth.

RESULTS: The 1994-95 growing season was not a kinder and gentler year. The fall to early spring period was characterized by very low precipitation, followed by near record rainfall in May and June, and then a dry summer. Damaging hail occurred in the spring near booting (depending on the treatment), significantly decreasing grain yields to the lowest levels in the last decade. NT and CT yields were about 35 and 25 bu/ac, respectively.

The pattern and amount of seedling emergence was the primary factor driving variation in final grain yield over the first four years. For CT treatments most soil water in the tillage zone was lost by evaporation after primary tillage. Exceptionally low rainfalls in September and October restricted seedling emergence patterns in CT treatments for two of the five years. Restricted germination in NT treatments resulted from dry seedbeds during September, 1995 for the first time in five years Delayed and spatially variable seedling emergence, and reduced plant densities at maturity occurred when germination was restricted by insufficient rains after planting. This led to lower biomass throughout the growing season, reducing yields, while increasing soil erosivity and weed populations.

FUTURE PLANS: This long-term experiment will be continued. SHOOTGRO and RZWQM modeling efforts utilize the field data, and initial manuscripts are in preparation. If feasible, the probability of years with low Sept/Oct rainfall will be predicted to determine the risk of stand establishment failure for CT systems in the western Great Plains.

INTRODUCING WBCT, THE WATER BALANCE AND CHEMICAL TRANSPORT SCIENCE MODULE FOR GPFARM

M. H. Nachabe, L. R. Ahuja, M. J. Shaffer, P.N.S. Bartling, J. C. Ascough II,
M. K. Brodahl, and D. Edmunds

PROBLEM: The USDA-ARS Great Plains Systems Research Unit is developing a computer-based decision support system at the whole farm level to manage agricultural cropping systems in the Great Plains. The goal of GPFARM, Great Plains Framework for Agricultural Resource Management, is to provide an operational framework for farm/ranch decision making. Because water quality and quantity are two of many user decision variables in GPFARM, there was a need to introduce a simple, yet reliable and practical, Water Balance and Chemical Transport (WBCT) science module into GPFARM. The objectives of WBCT are (1) to provide a daily soil-water budget to assess crop water stress for irrigation design and crop growth, and (2) to estimate the transport of surface applied agrochemicals in the soil profile and in runoff.

APPROACH: The simplicity of WBCT is dictated by the fact that GPFARM is a management tool rather than a comprehensive research model. The water balance in WBCT module simulates (I) interception by plants, (ii) precipitation and snow melt, (iii) infiltration and runoff, (iv) soil water redistribution and deep percolation, (v) soil-water evaporation, and (vi) plant transpiration and root water uptake. Modeling of these processes is described in detail in Chapter I of the user manual for GPFARM. Chemical transport is simulated in WBCT using a sequential mixing approach. This approach is similar to solving the advection-dispersion equation, but with dispersion generated numerically. WBCT is capable of simulating the movement of three pesticides simultaneously and have provisions for chemical soprtion to the soil matrix (linear sorption assuming instantaneous equilibrium) and pesticide degradation. Running WBCT requires (1) initial conditions for water content and residual nitrate mass, (2) soil hydraulic parameters, and (3) daily driving variables. The soil hydraulic parameters were estimated by a separate module called SPROP. SPROP computes the soil hydraulic parameters from soil texture and implements the effects of soil management, e.g. tillage, crop residues, soil crust, and macropores, on the estimation of these parameters. The daily driving variables for WBCT include precipitation, irrigation water, air temperature, potential evapotranspiration, and masses of pesticide and nitrate applied at the surface.

RESULTS: We completed the coding of WBCT and SPROP in FORTAN 77. We also successfully linked WBCT to the framework of GPFARM and to other science modules developed by scientists of the GPSR. Chapter I of the user manual (which describes the modeling of the processes in WBCT) was developed, but still needs refinements before it can be published.

FUTURE PLANS: We plan to complete the documentation of WBCT. This documentation will also include the test and validation of the simple modeling techniques introduced in WBCT. Given the uncertainty in the field and the long term objectives in agricultural management, the simple modeling techniques in WBCT might be as useful as rigorous mathematical models.

TESTING WBCT, THE WATER BALANCE AND CHEMICAL TRANSPORT MODULE FOR GPFARM

M. H. Nachabe, L. R. Ahuja, M.J. Shaffer, G. Butters[1]

PROBLEM: Before distribution for public use as part of GPFARM, WBCT shall be (1) tested within the modular modeling framework of GPFARM, and (2) validated independently of GPFARM. Independent validation of WBCT shall include both conceptual/physical validation of the processes in the model and field validation.

APPROACH: For conceptual validation, we compared the simple Green and Ampt infiltration routine in WBCT with CHEMFLO, a rigorous mathematical model developed by the EPA. The tests were performed for sand loam, loam, and clay loam. For field validation, we used data on bromide leaching. Bromide was applied at the bare soil surface, and water was sprayed with a sprinkler. Different volumes of irrigation water were applied at fifteen dates to generate highly transient conditions suitable to test WBCT. Daily potential evaporation and soil hydraulic parameters were measured and used as input in WBCT. Bromide and water content profiles were sampled to a depth of 2.5 meters at times 4, 18, 33, and 68 days from the time of application of the bromide. The total bromide mass in the profile (in kg/hectare), the location of the center of mass (in centimeter), and the spread (the standard deviation in cm) around the center of mass were calculated from the measured profiles.

RESULTS: The difference in predicted runoff between WBCT and CHEMFLO was less then 2%, 5%, and 15% for sand loam, loam, and clay loam respectively. During redistribution, the difference in the water content profiles between the two models was negligible for the three soils. We judged this difference reasonable and justified using the simpler techniques in WBCT. We observed about 15% loss of mass in the measured bromide profile in the first three sampling times, and over 50% loss of mass at 68 days. Therefore, this last data set was ignored in our analysis. On the other hand, the model preserved the total mass of the chemical in the profile at all times. Also the predicted location of the center of mass was within 1 cm from the measured bromide center of mass. The measured dispersivity (from profiles at 4 and 18 days) was 6 cm. This value is typical of dispersivity values reported by researchers. This dispersivity, however, increased to 78 cm, over an order of magnitude increase, for profiles sampled at times 18 and 33. For field soils, this increase is enhanced by evaporation near the surface. Gravity forces and evaporation act in opposite directions which stretches and flatten the chemical profile, thus increasing the spread.

FUTURE PLANS: We plan to do more field and conceptual validation of WBCT and other soil modules as a package using data from Coshocton, OH lysimeters and elsewhere.

[1] CSU, Dept. of Soil and Crop Sciences

REGIONAL ANALYSIS OF CONTROLS ON SOIL CARBON LEVELS

K.H. Paustian[1], E.T. Elliott[1], C.V. Cole[1]

PROBLEM: Models are needed to evaluate interactions between agriculture and climate change as they affect greenhouse gas emissions and the global C balance. A new version (4.0) of the Century model has been developed to facilitate simulation of complex cropping systems. To rigorously analyze the effects of management and climate on soil C dynamics, a thorough multi-site validation is needed to assess limitations and uncertainties in applying the model for local and regional applications.

APPROACH: A modeling database has being assembled of benchmark data (obtained with funding from EPA) from 35 long-term field experiments across the U.S. and Canada. Climate, crop production, soil and management information provide the necessary initialization and validation data for simulations of historical changes in soil C. Model analysis is being conducted on a subset of 17 sites, located in the Great Plains and Corn Belt. We are also simulating management systems under climate change scenarios for increased temperature and/or increased CO_2.

FINDINGS: Information for all the long-term sites have been incorporated into the database. Century simulation of historical C dynamics have been completed for 15 sites. Additional climate change simulations have been performed for 8 of the sites. A detailed analysis of management, climate and CO2 interactions was performed on four sites along a evapotranspiration gradient in E. Colorado and W. Nebraska. Soil C responded more to differences in management systems, i.e. wheat-fallow, wheat-corn-fallow and continuous cropping, than to climate and CO2 changes (as predicted by the UKMO general circulation model, 2XCO2 scenario). Under doubled CO2 and with climate change C inputs to soil increased by 25-30%. With reduced fallow systems under no-till, soil C increased by 20-30% after 50 years under the 2XCO2 scenario, while soil C under wheat-fallow was reduced or only slightly increased.

FUTURE PLANS: We will continue baseline (historical period) model analyses for the two sites which have not yet been modeled and complete the analyses of potential climate change effects for all sites.

[1] CSU, Natural Resources Ecology Laboratory

CALIBRATION AND EVALUATION OF RZWQM

RZWQM Development Team
(Alphabetic order: L. Ahuja, H. Farahani, J. Hanson, K. Rojas, M. Shaffer)

PROBLEM: The USDA/ARS Root Zone Water Quality Model (RZWQM) is a comprehensive simulation model designed to predict hydrologic and chemical response, including potential for ground-water contamination, of agricultural management systems. The model is also capable of predicting the relative response of various crops (corn and soybean at this time) to changes in soil water and nutrients for different management practices. RZWQM is being applied to simulate "best management practices" (BMPs) for the Management Systems Evaluation Areas (MSEA) research sites in the midwestern states of Iowa, Minnesota, Missouri, Nebraska, and Ohio and for a site in Colorado. For the model to provide useful information regarding BMPs, it was calibrated and evaluated for the specific locations.

APPROACH: Researchers at each site collected data suitable for calibrating and evaluating RZWQM. Generally, data collected for one of the experimental years were used for calibration and data for other years were used for evaluation. Data from irrigated and dryland sites in Colorado were also available for this exercise. The target crops for this exercise were field corn and soybean. Data generally available for the calibration process included management records, soil water and nitrogen profiles, crop yield, aboveground biomass at harvest, nitrogen content of the aboveground biomass at harvest, maximum leaf area index, and total nitrogen in the soil profile at harvest. For the model to work appropriately, we initiated an extensive calibration effort.

RESULTS: The model was calibrated and evaluated for corn and soybean at several sites. The model must be properly calibrated for soil water dynamics and nitrogen decomposition and leaching before it can simulate plant production. When following this procedure, the generic plant production component can be calibrated using only five parameters. Calibration errors of less then 10% of measured field values for aboveground biomass and yield were accomplished for the calibration data sets. Evaluation results were generally promising. In some cases, discrepancies occurred in predicting nitrogen or water content in the soil profile, particularly for the Missouri no-till management system, resulting in larger deviations in predicted crop biomass and yield.

FUTURE PLANS: Further work needs to be done toward: (1) improving the definition of nitrogen mineralization pools; (2) refining algorithms of plant responses to water stress; and (3) determining how best to simulate the effects of tillage treatment on soil water and nitrogen dynamics. RZWQM will be made more user-friendly by developing a graphical users interface to the program.

DEVELOPMENT OF GPFARM SCIENCE SIMULATION MODULE

M.J. Shaffer, P.N.S. Bartling, M.K. Brodahl, L.R. Ahuja,
M.H. Nachabe, J. Ascough, B. Vandenberg, J.D. Hanson, D. Edmunds,
L. Wiles, G.S. McMaster, L. Deer-Ascough, and H. Farahani

PROBLEM: A need exists for an integrated modeling package capable of simulating agricultural production systems in a whole farm setting using time and spatial scales suitable for the objectives of the GPFARM decision support system. Major components include crop and animal production, soil water and solute transport, nutrient cycling, evapotranspiration, tillage and residue effects, surface runoff and erosion, pesticide interactions, and weed management. The system model must be capable of simulating many different crops (including animals) in a multi-year rotational system for both irrigated and dryland conditions.

APPROACH: Existing technology and submodules were selected that are approximately suitable for the project objectives. Modifications and adaptations are being made to make these modules more appropriate for GPFARM. Basic calculations models written in FORTRAN and Visual Basic are being integrated into a control framework written in C++. The objective is to produce an integrated package capable of simulating soil-plant-animal processes for individual, but interacting management units in fields across a farm.

RESULTS: An alpha version of the GPFARM science simulation package was completed that combines FORTRAN and Visual Basic modules at the calculations level with an object-oriented C++ framework that manages the overall system integration, obtains input data from the user interface, and reports the results back to the interface. We are using modules derived from the EPIC plant growth model, the NLEAP nutrient model, the SPUR range model, the Green and Ampt and simplified Darcy approaches for water infiltration and redistribution and solute transport, the GLEAMS model for pesticide interactions, the S-W model for evapotranspiration, the GWM model for weed management, the WEPP approach for tillage effects, and the RUSLE model for soil erosion. Results have indicated that the mixed language approach using Microsoft C++ and compatible FORTRAN 90 plus Visual Basic 4.0 provides an effective science module base that can be easily integrated with any relational database or user interface such as the GPFARM Windows 95 Visual C++ user interface, while maintaining FORTRAN and Visual Basic code that can be tested and further upgraded by contributing scientists.

FUTURE PLANS: The alpha version will be further evaluated and upgraded to preliminary and advanced beta versions suitable for testing and evaluation by a range of users as well as integration with the GPFARM economics package and the Visual C++ user interface. This includes development of an events module that allows introduction of fixed-date events and events that are scheduled based on user-supplied rules and a defined state of the system. Additional simulation modules for items such as insects and diseases may also be added in the future.

SIMULATION OF REGIONAL SOIL NITROGEN GAS FLUXES USING NLEAP

M.J. Shaffer, C. Xu, M.K. Brodahl, R.F. Follett, and G. Hutchinson

PROBLEM: A need exists for an effective and efficient means of simulating emissions of nitrogen gases from soils across broad geographical areas as a function of soil properties, climate, and management inputs. The NLEAP model was designed as a national tool for nitrogen management and nitrate-N leaching and contains an appropriate submodel for total soil nitrogen gas production. NLEAP has already been adopted by SCS as a primary tool for nitrogen management and water quality evaluations.

APPROACH: This is a simulation modeling project with some field and laboratory work required to fill critical knowledge gaps, provide specific model validation data, and interact with project cooperators. The primary tasks of the project are to (1) extend the NLEAP denitrification submodel and related submodels to provide estimates of emissions of individual soil nitrogen gas pool components (e.g., N_2, N_2O, and NO_x), (2) test and validate the expanded NLEAP model using a range of data sets from across the United States and elsewhere, and (3) demonstrate the utility of using the NLEAP model in conjunction with a Geographical Information System (GIS) to estimate soil emissions of N_2, N_2O, and NO_x gases across broad landscapes and regions. Specific soil properties modeled will include nitrate-N levels, degree of soil aeration, amount of available carbon, pH, sulfide levels, temperature, and reductase levels. NLEAP will be interfaced to operate directly with available GIS computer software such as GRASS and IDRISI. Emphasis will be placed on the identification and simulation of cropping practices that minimize the emissions of N_2O and NO_x gases from soils.

RESULTS: Review of the literature and the existing NLEAP model has identified areas of the model that need expansion to accommodate the greenhouse gases. These include revision of the nitrification submodel to allow production of N_2O, expansion of the denitrification routines to separate N_2O, Nox, and N_2, and improved linkages of the NLEAP N transformation processes to collect specific soil gas and related processed information. Field experimental plots were established at ARDEC under irrigated corn to provide specific model validation data. Soil samples were collected from each plot to a depth 5 ft at increments of 1 ft in the spring of 1994 and 1995 for analysis of NO_3-N and NH_4-N. Work for 1996 will focus on field gas sample collection and analysis, and on development of trace gas algorithms for NLEAP. A lab. experiment will be conducted to test the effects of soil profile characteristics on N_2O and N_2 gas emission rates at different soil temperatures, water contents, and nitrate concentrations.

FUTURE PLANS: The research will produce a modified and extended NLEAP model suitable for use by SCS and others (including international groups) that is capable of simulating emissions of N_2, N_2O, and NO_x gases from soils as a function of soil properties, climate, and management across broad geographical landscapes. Management techniques will be identified that minimize emissions of N_2O and NO_x gases from soils. The refined and extended NLEAP model will provide regional, national, international decision aid capability.

DEVELOPMENT AND ENHANCEMENT OF SUBMODELS FOR CROP-WEED INTERACTIONS, SURFACE RESIDUE DECOMPOSITION, AND MINERALIZATION OF SOIL ORGANIC MATTER

M.J. Shaffer, L.R. Ahuja, G. McMaster, L. Wiles, R. Aiken,
M. Brodahl, M. Vigil, P. Westra[1], R. Waskom[2], and J. Radke[3]

PROBLEM: Development of research models such as RZWQM, NTRM-MS, and our 2-d models, as well as work with application models such as NLEAP and GPFARM has identified knowledge gaps that need additional basic research. Crop-weed interactions, surface residue decomposition, and mineralization pools of soil organic matter are topics where additional field data and model development are needed.

APPROACH: Field plots have been established at CSU's ARDEC, the CSU Horticulture farm, USDA-ARS, Akron, CO, and with farm cooperators. These plots generally have multi-purposes and allow the introduction of studies that address the above problem areas. Specialized studies often can be added to existing projects where basic information on system inputs and outputs is already being collected. We are attempting to develop a fast laboratory method that is field correlated to quantify the fast soil organic matter pool. Surface residue decomposition studies are in progress at Akron and are being started at ARDEC and the CSU Hort. farm. We need detailed quantitative information on how surface residues decay as a function of the high spatial and temporal variability of the micro-climate that exists near the soil surface.

RESULTS: Plot studies at ARDEC involving proso millet invasion of corn have shown that both millet and corn yields are significantly reduced relative to monocultures of the same crops. This occurred both in the fertilized and unfertilized treatments. Soil N mineralization results from ARDEC and from farm fields have shown that rate of mineralization of soil organic matter is a strong function of recent management history. For example, ARDEC results for a commercial fertilizer site indicated annual soil mineralization rates of 85 and 92 lb N/acre under corn and millet, respectively. By comparison, the mineralization rate under a corn crop grown on a farm field fertilized with 20 t/acre of beef manure for each of the ten previous years was 300 lb N/acre/year.

FUTURE PLANS: These field studies will be continued for several years so that sufficient annual data sets can be collected to allow adequate model development and testing. The NTRM-MS model will be expanded to include several crops and associated weed species. A comprehensive surface residue decomposition model will be developed that simulates decay of standing dead, fallen residues, and fallen residues contacting or incorporated into the surface 1 cm of soil. The soil organic matter study will test the feasibility of using the autoclave method (or a related lab. method) to analyze samples for the N zero pool.

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[1]CSU Dept. of Plant Path. and Weed Science. [2]CSU Dept. Soil and Crop Science.
[3] ARS, National Soil Tilth Lab., Ames, IA.

NLEAP TECHNOLOGY TRANSFER AND DEVELOPMENT OF REGIONAL DATABASES

M.J. Shaffer, M.K. Brodahl, P.N.S. Bartling, R.F. Follett,
J. Marron[1], and S. Aschmann[1]

PROBLEM: Given the current state of the national farm economy and the renewed concerns about groundwater pollution from nitrates and pesticides, there is an urgent need to find ways to optimize on-farm productions for profit and yet minimize adverse environmental impacts. Farm and natural resource managers lack suitable tools which can provide answers now before additional damage is done to the farm economy and the nation's soil and groundwater resources.

APPROACH: The NLEAP model is available for use now. At a minimum level, the user needs to know how to acquire and input data, initiate the simulation, and access the simulation results. However, effective use of a simulation model requires the user to understand the system being simulated well enough to provide proper data input and to interpret the simulation results.

RESULTS: The NLEAP model is one of 5 water quality models adopted for use by the U.S. Natural Resource Conservation Service (NRCS). The NRCS national NLEAP model leadership duties have been transferred to Johnathan Hawes (Richmond, VA). However, we continue to work with Dr. Stephanie Aschmann and the national NRCS NLEAP team to complete the NRCS NLEAP workbook. This book and associated training files will be distributed within the NRCS over the Internet. We have been working with the NRCS NLEAP model team on how to continue NLEAP technical transfer under the new organization structure. NLEAP technology has been incorporated into PLANETOR (Minnesota extension), an agricultural economic and enviromental impact analysis software package. In addition, NLEAP technology is currently being incorporated into models under development by Ag. Canada and Louisiana State University. A CRADA has been negotiated with J.R. Simplot Company to bring the NLEAP simulation technology into a Simplot software product dealing with fertilizer recommendations and site-specific farming. The NLEAP Soil and Climate databases continued to be tested with the final database West 2 continuing to be developed. Final West 2 soils data are available and being used by NRCS trainers. A limited West 2 Climate database, developed for NRCS trainings, includes data for Oregon, Washington, Idaho, and Montana. The completion of the West 2 Climate data continues to be challenged by the lack of information available to derive relationships for over-winter evaporation required by NLEAP.

FUTURE PLANS: We will continue to develop new technology transfer strategies in cooperation with NRCS and to jointly refine methods for improved use of the model in addressing NRCS water quality issues. NLEAP ARS training courses will continue to be provided on a regular basis each year. NLEAP database development will continue for the remainder of the western U.S. and include investigating additional data resources, and approaches to estimating winter evaporation/sublimation.

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[1]NRCS, Western National Tech. Center, Portland, OR.

DEVELOPMENT AND TESTING OF A MECHANISTIC MODEL FOR SOIL GAS FLUX AND REACTION

M.J. Shaffer, C. Xu, L.R. Ahuja, D. Reicosky[1], and A. Mosier

PROBLEM: Gaseous emissions and transport associated with soil involves complex systems with multi-phase components. Changes in the biological, chemical, and physical composition of the soil can have direct effects on carbon and nitrogen cycling processes, and on the surface/sub-surface evolution and phasic (aqueous and gaseous) transport of soil gases. The development of a comprehensive soil gas exchange model, integrated with process-based models simulating the dynamics of the biological and chemical soil processes, and water and heat flow, is needed to provide detailed understanding and quantitative assessment of the dynamics of the C and N balance in the soil, and fluxes of greenhouse gases.

APPROACH: A finite difference model was developed to simulate advective-dispersive and diffusive transport of the dissolved and gaseous forms of CH_4, CO_2, N_2O, and O_2 in the soil. Movement of water and heat in the soil and profile distributions of soil moisture content and temperature under saturated, partially saturated, and/or unsaturated soil conditions were determined by linking the gas transport routine to a water and heat flow (CHAIN-2D) model. The dynamic concentrations of aqueous CH_4, CO_2, N_2O, and O_2 in the soil were determined from a direct interaction between the soil gas, heat, and water transport routines with the root growth, soil chemistry, and nutrient cycling submodels. These include microbe-mediated processes sensitive to the spatial and temporal variations in soil moisture, temperature, concentrations of O_2, CO_2, C, and N substrates. A bicarbonate buffering system was included, in addition to Henry's Law, to quantify the equilibrium concentration of CO_2 in the aqueous and gaseous phases, and assess soil pH.

RESULTS: The project has developed a comprehensive soil gas exchange model for simulating surface and subsurface exchange of O_2, CO_2, CH_4, and nitrogen gases in unsaturated and saturated soils. Comparisons of the simulated profiles of soil moisture, temperature, root length density and biomass, and CO_2 concentration have indicated good agreement with the measured data taken from a fertilizer field experiment in a shortgrass steppe. During 1995, various aspects of the model were evaluated and a field experiment was established to collect validation data on N_2O, NO_2, and N_2 gas emissions under irrigated corn and millet for fertilized and unfertilized conditions. Various aspects of the model were evaluated relative to the needs of the NLEAP soil gas project. We anticipate making runs with the research model to help provide information.

FUTURE PLANS: We will continue to evaluate the 1- and 2-dimensional models for use in RZWQM, NTRM-2D, NLEAP, GPFARM, and other comprehensive process models we have in progress. Technology developed in this study will be evaluated and downsized for use in the NLEAP gas modeling project and in GPFARM. Close collaboration will be maintained with other on-going soil gas research.

[1]ARS, N.C. Soil Conserv. Res. Lab., Morris, MN.

APPLICATION OF THE NLEAP MODEL TO REGIONAL NITRATE LEACHING IN NORTHEASTERN COLORADO

M.J. Shaffer, M.D. Hall[1], R.M. Waskom[2], J. Boyd[2], R. Schierer[3], D. DuBois[4], D. Wagner[5]

PROBLEM: High levels of nitrate-Nitrogen (NO_3-N) in drinking water supplies pose health risks to humans and livestock. NO_3-N in and derived from fertilizers and manures applied to croplands can be moved into underlying aquifers. This nonpoint NO_3-N pollution is prevalent in areas with alluvial aquifers where aquifers tend to be shallow and soil profiles contain coarse textured soils. Farm management of nitrogen and water needs to be carefully considered on areas vulnerable to NO_3-N leaching.

APPROACH: Mechanistic modeling, Geographic Information System (GIS) technology, and field research have been combined to address NO_3-N leaching in an area in northeastern Colorado where irrigated agriculture occurs over the shallow South Platte River alluvial aquifer. Groundwater modeling was used in conjunction with NLEAP simulations to help clarify the processes contributing to nitrate hot spot stability and enable long term simulation of the effects of BMP implementation on aquifer water quality. Data collected from a manured field site near Lucern, CO were used in conjunction with NLEAP simulations to gain a better understanding of how minealization of manures contributes to nitrate leaching.

RESULTS: Farm field and NLEAP simulation results for the Lucern site show that 10+ years of continuous annual beef manure application at the rate of 20 t/acre resulted in an elevation of the fast soil organic matter pool from about a 5 percent baseline to 20 to 30 percent of total SOM. Continuous NLEAP simulations of manure applications for 11 years were effective in estimating the size of the fast pool as measured during 1994 and 1995. A potential BMP was developed for the manured site that involves irrigation management in conjunction with manure applications on alternate years. Regional NLEAP/groundwater simulations for a 14,000 ha region near Gilcrest, CO show that, with proper management assumptions, simulated concentrations of NO_3-N in leachate from agricultural areas are comparable to concentrations observed in underlying groundwater. The simulations also indicate that other factors including leakage from irrigation delivery ditches and extensive pumping have a considerable effect on groundwater flow paths, therefore, on accumulation and stability of NO_3-N hot spots.

FUTURE PLANS: The manured field site will continue to be monitored and studied in an effort to obtain a long-term data set for mineralization of soil-applied beef manure. With the calibrated NLEAP/groundwater simulation system constructed, long-term simulations of BMPs will be conducted to estimate resulting impacts on NO_3-N concentrations in the groundwater.

[1]CSU, Earth Resources Dept. [2]CSU Dept. of Soil and Crop Science. [3]NRCS, Lakewood, CO. [4]North Front Range Water Quality Planning Assoc. [5]CSU Dept. of Chem. and Bioresource Eng.

SOIL ORGANIC CARBON CHANGES AS AFFECTED BY TIME AND ROTATION INTENSITY ACROSS AN EVAPOTRANSPIRATION GRADIENT

L.A. Sherrod, G.A. Peterson[1], D.G Westfall[1], and G.S. McMaster

PROBLEM: The practice of summer fallow within the Wheat-Fallow (WF) cropping system in the Central Great Plains is a costly practice environmentally. Research hasshown substantial losses of organic carbon (C) during the past 50-70 years of crop production. By implementing no-till management, conservation of soil moisture is increased enough to support more crops over time than traditional WF. More intensive cropping under no-till management causes an accumulation of crop residues on the soil surface which promotes microbial growth on and near the soil surface which promotes increases in C levels.

APPROACH: Three research sites in CO were established in 1985 across an ET and soil gradient (Catena). All sites had been under conventional WF production practices for over 50 years. Cropping systems managed by no-till practices were imposed across these catena's with two replications present and every phase of each cropping system rotation represented each year. These systems are Wheat-Fallow (WF), Wheat-Corn,Fallow (WCF), Wheat-Corn-Millet-Fallow (WCMF), and opportunity cropping (OPP). Continuous grass (CG) was also included as a comparison of the native prairie. Soils were sampled in 1986 in 3 depth increments of 0-2.5 cm, 2.5-5 cm, and 5-10 cm and each year from 1989 to present. All five cropping systems will be included in this study. This research will study changes in C and N over time as well as the differences between initial and final carbon levels.

FINDINGS: Rotations with less fallow time are showing C increases. C levels are showing a positive response in the WCMF, OPP, and CG rotations in the 0-2.5 cm depth whereas WF and WCF are maintaining or showing a negative response. With the depths summed to 10 cm, cultivated systems maintained initial 1986 C levels with the exception of WCF. CG showed increases in C in all depths at all sites. The high ET site (lowest initial C), gained or maintained in all rotations except WF. The site (highest initial C), had the greatest losses.

FUTURE PLANS: Changes in soil organic carbon and in soil organic nitrogen will continue to be monitored. Residue quantity and quality will also be addressed as factors that relate to how fast these inputs are converted into the organic pool.

[1] CSU, Dept. Of Soil & Crop Sciences

EVALUATION OF ROOT ZONE WATER QUALITY MODEL (RZWQM) FOR WATER QUALITY IMPACTS OF AGRICULTURAL MANAGEMENT PRACTICES.

P. Singh[1] and R.S. Kanwar[1]

PROBLEM: Computer simulation models such as RZWQM provide a cost-effective and time saving alternative to lengthy and expensive field studies for evaluating various agricultural management options. However, the model performance has to be critically evaluated against observed data collected in the controlled experiments before the model can be accepted as a tool for evaluating management scenarios. This project focuses on the critical evaluation of the model performace.

APPROACH: RZWQM (V.2.5)was calibrated and evaluated for subsurface drain flows, NO^3-N losses with subsurface drain flows, and crop yields using three years data from Iowa. The model's performance was evaluated for four tillage systems (chisel plow, moldboard plow, no-tillage and ridge-tillage). The model's performance was also evaluated for pesticide transport in soil under moldboard plow and no-tillage systems. The effect of variable nitrogen input on crop yields and NO^3-N losses with subsurface drain flows was evaluated using 20 years weather data. This required the recalibration of N-uptake in the model. Also, the macropore component of the model was evaluated for moldboard tillage treatment. Various macropore parameters were calibrated to improve the predictions of pesticide losses with subsurface drain flows.

RESULTS: The model simulations have shown a good agreement between the measured and predicted subsurface drain flows. Simulated tillage effects on subsurface drain flows were consistent from year to year (maximum flow under no-tillage system and minimum under moldboard plow system). The simulation results on pesticide transport in the vadose zone were within the range of observed data. The model also showed a clear effect of variable N-input on crop yields and NO^3-N losses in the subsurface drain flows. Macropore evaluation results for moldboard tillage system show a considerable effect of macropores on pesticide concentrations in subsurface drain flows. However, there is a need for more accurate data-sets for initial conditions, and rainfall intensities. Also, more frequent sampling of subsurface drain flow in the field is necessary to obtain accurate information of pesticide concentrations in the subsurface drain flows.

FUTURE PLANS: Future plans include: a) calibration and evaluation of the macropore flow paramenters for no-tillage system b) simulate long-term impacts of chemical (multiple N-application, banding, manure application etc.,) management and crop rotation on water quality. Also, one or two plots will be selected from NERC, Nashua to collect data on initial conditions, rainfall intensities, water table depths and more frequent subsurface drain flow samples for a rigorous evaluation of the macropore flow component during the summer of 1996.

[1] Iowa State Univ., Dept. Of Agr. and Biosystems Eng., Ames, IA.

ROOT DISTRIBUTION UNDER ALTERNATE FURROW IRRIGATION

R. H. Skinner, J. D. Hanson and J. G. Benjamin

PROBLEM: Alternate furrow irrigation of corn, with fertilizer placement in the non-irrigated furrow, provides a potential means of reducing nitrate leaching and groundwater contamination. Lack of root growth in the non-irrigated furrow, however, may limit root growth and N uptake. Separating fertilizer from the water supply may also reduce N uptake and plant growth because N supply to the root system in high productivity systems relies heavily on mass-flow transport in the soil solution. Several studies have shown that roots tend to proliferate in areas where water and/or nutrients are found in abundance, however, the effects of spatially separating water and nutrients within the soil profile on root distribution have not been investigated.

APPROACH: Water and N were applied in a 2x2 factorial with every furrow vs. alternate furrow irrigation, and furrow vs. ridge fertilizer placement. Corn roots and shoot were sampled four times during the growing season, at V6, V12, R1 and R6 in plots fertilized with ^{15}N-labeled fertilizer. Soil cores for root distribution, root nitrogen concentration, and soil water and nitrate determinations were taken in 30 cm increments to a depth of 120 cm from a 3 x 3 sampling grid centered over single corn plants which were harvested for shoot biomass and N content.

RESULTS: The spring of 1995 was very wet so that irrigation treatments did not begin until after the V6 harvest. Nitrogen placement only affected root development at V6 when ridge placement resulted in a 50% increase in root weight compared with furrow placement. All differences between ridge and furrow placement had disappeared by V12. Every furrow irrigation increased root weight at V12 and R1, and concentrated roots beneath the ridge compared with alternate furrow irrigation. Root weight reached a maximum at R1 then began to decrease in the upper 30 cm. Roots in the 90-120 cm layer continued to grow throughout the experiment. Under these conditions, withholding irrigation water from the fertilized furrow did not reduce root growth compared with furrows where water and fertilizer were both present. In fact, the greatest root weight at R1 was in the furrow that received neither irrigation water nor fertilizer N (alternate furrow irrigation, ridge fertilizer placement).

FUTURE PLANS: Data collection will continue in 1996.

CONTROL OF NITROGEN PARTITIONING IN PERENNIAL GRASSES FROM ECOSYSTEMS WITH LIMITED NUTRIENT SUPPLY

R. H. Skinner and J. D. Hanson

PROBLEM: Experiments in controlled environments have suggested that more N is supplied in the xylem to shoots than can be used for shoot growth. Excess N is recycled back to the root for utilization in root production. The implication is that N partitioning is controlled by shoot utilization rather than by the root demand. These experiments are generally conducted, however, under conditions where root:shoot ratios are low and most of the N is partitioned to the shoot. This study will address the question of whether or not N recirculation occurs in range grasses growing under field like conditions where root:shoot ratios are high and where much more of the total N is partitioned to roots.

APPROACH: Nitrogen recycling was investigated in blue grama (*Bouteloua gracilis)* growing at the Central Plains Experimental Range (CPER). Intact plant and soil cores were collected from CPER on April 5 (before spring growth had commenced) and placed outdoors at the Agricultural Engineering Research Center (AERC) in Ft Collins. Harvests at AERC occurred on 19/20 June and 11 July, followed by companion harvests at CPER on 22 June and 12 July. Plants were divided into green shoots, stubble, old roots, and new roots. Precipitation was recorded and pots were weighted twice daily to determine evapotranspiration. Xylem sap was collected using a pressure chamber. Total N transport to the shoot was calculated by multiplying xylem N concentration by cumulative transpiration. N recycling will be determined by comparing N transport in the xylem stream with shoot N content. If recycling is occurring, N transport to the shoot will be greater than shoot N content. Results from CPER and AERC will be compared to determine if removing plants from the field in intact soil cores affects growth and assimilate partitioning.

RESULTS: At the first harvest, soil NH_4 levels in the cores at AERC were twice as high as in fresh cores collected from CPER (18 vs. 8 ppm, respectively). This difference disappeared by the second harvest. Soil NO_3 concentrations were low at both sites and for both harvests (<3 ppm). Increased NH_4 concentration at AERC did not result in a significant increase in shoot growth during the 3 wk growth period. Decomposition of old roots between the two harvests increased at AERC compared with CPER, however. Root:shoot ratio decreased between the first and second harvests because of the decrease in below ground dry matter. Shoot growth was offset by a decrease in stubble dry weight resulting in above ground dry matter remaining constant between harvests. Xylem N concentration depended on exudation rate and ranged from 1.4 to 6.1 μg/μl. Plant N content has not been analyzed so estimates of N recycling have not yet been made.

FUTURE PLANS: These experiments will be repeated in 1996.

CARBON AND NITROGEN REMOBILIZATION FOLLOWING DEFOLIATION

R. H. Skinner, J. A. Morgan and J. D. Hanson

PROBLEM: Following defoliation, both photosynthesis and N uptake cease or are greatly reduced for a period of time. Initial shoot regrowth depends on reserve N and C stored in root and crown tissue. We are interested in determining the relative importance of stored C and N in the regrowth process, which specific reserves are remobilized, how soil N concentration and atmospheric CO_2 affect reserve remobilization, and how the re-establishment of root:shoot ratio following defoliation can best be modeled.

APPROACH: A forage legume (alfalfa), C_3 grass (western wheatgrass), and C_4 grass (blue grama) were grown in growth chambers with two atmospheric CO_2 concentrations and two soil N concentrations to provide a range of C and N storage levels in crowns and roots, as well as a range of external supply conditions for regrowth. Four growth chamber experiments will be conducted (two at ambient and two at elevated CO_2). Following defoliation, sequential harvests were made at 0, 4, 7, 10, 14, and 20 d, and plants separated into root, crown and regrowth tissue. Total dry weight was determined for each tissue, and N pools were partitioned into buffer-insoluble proteins, buffer-soluble proteins, and low molecular weight N compounds (amino acids, NO_3, etc.). Carbon was partitioned into structural dry matter, water soluble carbohydrates, and starch. Nitrogen and carbon remobilization and uptake were determined by changes in the respective pool sizes of each tissue. Results will be compared with several root:shoot partitioning models to determine which best describes the regrowth process.

RESULTS: The first ambient and elevated CO_2 experiments have been completed, along with C and N analysis from the ambient treatment. Net C and N uptake ceased in alfalfa for the first 10 d following defoliation. The two grasses, however, accumulated dry matter throughout the experiment. Available C and N reserves, and reserve remobilization were greater in alfalfa than in the two grasses which had similar reserve levels. Remobilized N from alfalfa roots and crowns accounted for a maximum of 89 and 50% of total N in regrowth tissue in high and low N treatments, respectively. In blue grama, only 32% (high N) and 10% (low N) of the N in regrowth tissue came from reserves. Plants growing in low nutrient conditions appeared to be less dependent on reserves for regrowth, and used reserves more slowly than plants provided with an ample nutrient supply. Nitrogen stressed blue grama stopped accumulating N 10 d after clipping and began remobilizing N from crowns and regrowth back into the roots. Shoot growth continued, however, even though N accumulation had stopped.

FUTURE PLANS: The last two growth chamber runs will be completed during 1996 along with all C and N partitioning and analysis.

USE OF RZWQM TO EVALUATE PESTICIDE RUNOFF POTENTIAL OF NEW PRODUCTS BY AGROCHEMICAL INDUSTRY

P. Sweeney[1], L.R. Ahuja, and K.J. Rojas

PROBLEM: For registration of new pesticide products, the EPA requires that the agrochemical industries conduct certain field and modeling tests to evaluate their runoff potential. For modeling, they have been using an EPA model, PRIZM. The comparative evaluations over the last few years showed gross inadequacies of PRIZM. Recently, some industry scientists modified PRIZM to include a new non-uniform mixing modeling approach that was developed by us in ARS and used in RZWQM. The ZENECA Agrochemical company sent a post doctoral scientist to work with us on evaluating RZWQM for their applications.

APPROACH: The plan was to systimatically evaluate RZWQM against field data sets from two of the ZENECA's test sites, first the hydrology (runoff) component, then sediment loss, and finally the pesticide and a tracer chemical, Br, losses in runoff water and sediment.

RESULTS: After learning the scientific components and use of RZWQM, Dr. Paul Sweeney completed calibration of the model for runoff water and sediment loss during his six-month stay with us. It was found that for tilled field conditions, it was very important to consider the surface detention storage of water and its change with time from one rainstorm to another. The change in hydraulic conductivity due to crusting was another important factor.

FUTURE PLANS: We hope Dr. Sweeney will return here for another six months to complete the excercise -- evaluate pesticide and Br amounts in runoff, which are the main ultimate objectives.

[1] ZENECA Agrochemicals, England

PROTECTING WATER QUALITY BY SCOUTING WEED POPULATIONS

L. J. Wiles and E. E. Schweizer

PROBLEM: Weed control with herbicides is economic, convenient and effective. As a result, herbicides have lead the dramatic increase in the amount of pesticide applied. Approximately 70% of the total amount is applied to corn and soybean. Several herbicides are commonly detected in surface water and groundwater in the corn belt. Water quality could be enhanced by reducing the use of herbicides, and weed management could be more efficient if growers had more accurate, field-specific information about the composition and spatial distribution of weed populations. Thus, a 2-year field study was conducted in Colorado to develop scouting plans for obtaining the information about weed populations needed to use computer weed management models.

APPROACH: Weed seed bank and seedling populations were sampled in four pivot irrigated and four furrow irrigated commercial corn fields in eastern Colorado in 1993 and 1994. These fields were located on different sites each year. Before corn emergence, 1245 soil samples were collected on a square grid pattern in a 20-acre block. After corn emergence, weed seedlings were identified in a five foot length of crop row adjacent to each sample site. Time required for soil sampling and seedling counts was recorded.

RESULTS: The seed and seedling counts have been analyzed and mapped. Seedling populations consisted of 9 to 23 species in a field and seedbanks consisted of 7 to 19 species. However, just 2 to 6 species made up 90% of the seedbank or seedling population in a field. Spatial distributions were patchy and the counts had highly skewed distributions. The frequency distribution of counts could be described with a logarithmic with zeroes distribution in 26 of 104 cases for seeds and 23 of 94 cases for seedlings. A negative binomial distribution described the frequency distribution of counts in 23 cases for seeds and in 31 cases for seedlings. Based on the fitted distributions, the proportion of a field free of broadleaf weeds is estimated to range from 1 to 81%. From 11 to 50% of a field was estimated to be free of grass weeds. Maps indicate that the pattern of patchiness varied between fields. Maps of seedling and seedbank populations in a field were similar, although the correlation between seed and seedling counts was low. One objective of our research is to determine the cost of scouting seed and seedling populations. The time required to count the seeds in a soil core or seedlings in the quadrat was weakly related to density with large variation between individuals. For seeds, counting was more time consuming when the soil had a moderate to high sand content.

FUTURE PLANS: In 1996, we will conduct stochastic simulations based on our data and data from seedling studies in Nebraska to identify cost-effective scouting plans and to determine the value of spatially-variable weed management. We plan on meeting with at least three groups of consultants and growers to learn about current weed scouting practices. This information will help us develop scouting plans to be tested in the simulations.

THE WEED MANAGEMENT MODULE OF GPFARM

L. J. Wiles and C. M. Dunan

PROBLEM: A computer-based decision support system at the whole-farm level is being developed. This system, called GPFARM, will be capable of analyzing and developing strategic one to ten year management plants based on the predicted productivity of selected management options and environmental and economic risks. Crop rotations are often planned to address problems with weeds, and weed management can be a large component of the production costs and environmental risks of crop production. GPFARM must include a module that predicts the impact of weed management strategies on crop yield and weed population dynamics.

APPROACH: Our plan was to have the first version of the weed management module of GPFARM be a simple model based on the structure of the databases and simulation model of GWM (General Weed Management Model). GWM is a tactical decision support system for soil-applied and postemergence weed management decisions in row crops during a single season. However, it was difficult, if not impossible, to find the necessary data on weed seed production and seedbank dynamics to parameterize this model to predict weed population dynamics. We do not expect this data to be available in the near future. Therefore, we are developing a new model that requires less information on weed biology by summarizing over several processes of weed population dynamics. In our summary model approach, a population of a weed species is assumed to have a maximum rate of increase if it is not controlled, a maximum rate of decrease with complete control, and a seasonal pattern of emergence. The model estimates the proportion of the weed population that has emerged by the time of a weed control tactic and the proportion of the emerged population that is controlled so that the total level of control varies with the number, timing and efficacy of weed control tactics. Whether a population increases or decreases and the rate of change depends on the total level of control in a given year.

RESULTS: The model was developed and programmed in VISUAL BASIC with versions for stand-alone use and as a component of GPFARM. Model parameters and data are stored in ACCESS databases. Preliminary validation has been with data from experiments in the literature in which weed populations were studied under different crop rotations, tillage systems, and herbicide use. The model appears to capture the impact of crop sequences and tillage systems. We have parameterized, but have not validated, the model for wheat-fallow rotations in the Great Plains.

FUTURE PLANS: We will parameterize the model for other crop rotations of the Great Plains and we will continue to validate it. We plan to develop a survey to obtain expert opinion on the rates of increase and decrease of populations of individual weed species.

GREAT PLAINS SYSTEMS RESEARCH

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RANGELAND RESOURCES RESEARCH UNIT

Gerald E. Schuman, Research Leader
High Plains Grasslands Research Station
8408 Hildreth Road
Cheyenne, WY 82009
TEL: (307) 772-2433
FAX: (307) 637-6124

FTS2000: a03lccheyene@attmail.com
INTERNET: gschuman@lamar.colostate.edu

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5409-11210-001-03R	Seed treatment and sagebrush seedling vigor
5409-11210-001-04S	Wildland shrub seed biology
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MISSION STATEMENT

The research mission of the Rangeland Resources Research Unit is to develop an understanding of the interrelations of the basic resources that comprise rangeland ecosystems. Research is directed toward the development of science and technology that contributes to sustainable and productive pasture and rangeland ecosystems in the Central Great Plains.

TECHNOLOGY TRANSFER

1. Bai was a co-instructor for a class on weed and crop ecology at the University of Wyoming, Dept. of Plant, Soil & Insect Sciences.

2. Bai presented seminars to UW, Plant, Soil & Insect Sciences and Rangeland Ecology and Watershed Management departments on the 'Effect of post-harvest handling on sagebrush seed quality' and on 'Range Management in China'. He also presented a seminar to the Grassland Institute, N.E. Normal University, P.R. China, on 'The ecophysiology of winterfat and sagebrush'.

3. Booth has worked closely with Western Polyacrylamide, Inc., on evaluating synthetic polymer and weed barrier in conjunction with the closed hole punch planter.

4. Booth, Schuman and Hart participated in the High School Research Apprentices program. The objective of this program is to expose the students to careers in agricultural sciences.

5. Booth served as President of the Wyoming Section, Society for Range Management.

6. CPER staff hosted several technical groups from the U.S., Slovakia, Turkey and Native Americans who visited and toured the Central Plains Experimental Range.

7. CPER staff hosted school children from Fort Collins (96) and Pierce, CO, (36), who toured the Central Plains Experimental Range.

8. Hart delivered lectures to "Nutritional Management of Range & Pasture Herbivores" class at UW and to "Range Ecosystem Planning," "Environmental Conservation" and "Primary Production and Decomposition" classes at CSU.

9. Hart presented paper at the Missouri Valley History Conference, Omaha, NE; the annual meeting of Southwest and Rocky Mountain Division, American Association for the Advancement of Science, and the Great Plains Ag Council task force "Grazing Management in Riparian Areas" in Lincoln, NE.

10. Hart presented talks on the Unit's research at East High School Ecofair, Cheyenne, WY; at "On the Farm Day," Ft. Collins, CO; and at High School III, Cheyenne, WY.

11. Booth, Schuman, Frasier and Hart presented research findings at the Society for Range Management national meeting in Phoenix, AZ.

12. Frasier serves as Editor for the Journal of Range Management and Rangelands. Schuman serves as Associate Editor for the Journal of Range Management.

13. Griffith atteneded and presented a poster at the Soil and Water Conservation Society annual meeting.

14. Hart, Bai, Booth and Frasier presented papers at the 5th International Rangeland Congress, Salt Lake City, UT.

15. Hart and Schuman spent a day discussing range research involving complimentary pastures, CRP, and management strategies with NRCS range conservationist and regional plant materials specialist.

16. Hart, Schuman and Booth visited with a group of scientists from Argentina, South Africa, Germany, Japan and Australia on rangeland research.

17. Morgan, Hart, Booth and Frasier developed and submitted popular research articles to popular publications such as Colorado Rancher-Farmer, Wyoming Stockman-Farmer, and Western Beef Producer magazines.

18. Mueller filed patent applications on cactus harvester and despiner (despiner patent issued).

19. Peterson participated in career information fair at Laramie County Community college, which included approximately 300 participants.

20. Reeder, Hart, Booth, Taylor and Schuman attended and presented papers at the American Society of Agronomy/Soil Science Society of America/Crop Science Society of America meetings.

21. Reeder, Frasier and Schuman attended and presented papers at the conference Effects of Land Application of Biosolids in Arid and Semiarid Environments, Ft. Collins, CO.

22. Schuman serves as a member of the Soil Science Society of America committee on Soil Quality. This committee is defining the subject of soil quality and the role of the Society in this area.

23. Schuman, Booth and Hart discussed revegetation research and vegetation monitoring methodology with Neil Humphries from Great Briton.

24. Schuman, Hart, Booth and Morgan are members of regional technical committees and presented research summaries to the group on the Unit's research on related subjects.

25. Schuman served as Chairman of the 12th annual meeting of the American Society for Surface Mining and Reclamation and as co-chair of the program committee for the conference.

26. Schuman, Booth, Taylor, Griffith, Freeman, Mortenson and Heckart attended the 12th Annual Meeting of the American Society for Surface Mining and Reclamation, Gillette, WY. Schuman and Booth presented papers at the conference. Registration exceeded 400.

27. Schuman represented ARS at the Wyoming Governor's Natural Resources Conference to discuss and prioritize natural resource issues and participated in the Governor's Rangeland Tour and meeting.

28. Schuman gave a presentation on management alternatives for CRP lands at a rancher-farmer workshop at Pine Bluffs, WY.

29. Schuman serves as member of the steering committee for the Wyoming Abandoned Coal Mine Land Research Program administered by the Office of Research, University of Wyoming.

30. Taylor, Hart, Booth, Schuman, Freeman, Griffith, Mahelona, Clapp attended the Wyoming Section, Society for Range Management/Wyoming Chapter, Soil and Water Conservation Society meeting.

31. Taylor, Mortenson, Freeman, Mahelona and Schuman participated in the Wyoming Air National Guard "Star Base" program for 5th grade students in Laramie County School District #1, which involved approximately 150 students.

32. Taylor, Freeman, Hart and Schuman served as judges at the Pioneer Park Elementary School Science Fair.

33. Townsend's article on cicer milkvetch was published in "New Farm" magazine, which produced 292 requests for additional information on cicer milkvetch. Peterson Seed Company received over 100 requests for seed.

34. Unit staff participated in the Central Plains Experimental Range symposium where scientists and staff doing research at the CPER review past progress and discuss relevant research needs.

35. Unit continued to work with Laramie County Conservation District on several projects and keeps them appraised of research results.

36. Unit presented a Field Day at the High Plains Grasslands Research Station, September 15, to over 100 participating students, agency, and farm and ranch people. Poster presentations and field tours were used to describe the Unit's research program.

37. Unit scientists discussed with customer focus group research involving 1) uses of alfalfa for dryland grazing, 2) effects of grazing on rangeland health, and 3) the impact of future global change on rangelands and solicited inputs from them as to identification of research needs.

38. Unit is working closely with NRCS Cheyenne Grazing Lands Technical Team located at the High Plains Grasslands Research Station to develop technology transfer activities.

FREEZING TOLERANCE IN WINTERFAT SEEDS, PART I: SEED HYDRATION RELATED TO TEMPERATURE

Y. Bai[1], D.T. Booth and J.T. Romo[2]

PROBLEM: Freezing and near-freezing temperatures are part of the daily spring and fall regime to which plants of the Northern Great Plains of North America are exposed. For plants such as winterfat [Eurotia lanata (Pursh) Moq.], successful revegetation may depend on the seed's ability to hydrate, germinate, and begin growth at low temperatures; and, to survive periods of freezing stress. We wished to determine the effect of temperature on winterfat seed hydration as a pre-requisite to understanding freezing tolerance in hydrated seeds.

APPROACH: Winterfat diaspores were hand-collected in October 1994 from Matador, Saskatchewan, Canada; Sterling, Colorado, USA and Pine Bluffs, Wyoming, USA and stored in paper bags at room temperature until February 1995. Diaspores of the three collections were placed on moistened germination paper over plastic slant-boards and incubated them at 0, 5, 10 and 20°C in darkness. The experimental design was a Randomized Complete Block (RCB) with three replicates arranged over time. Ten diaspores were retrieved from incubators at 8 h intervals for each experimental unit. After removing bracts by hand, surface water was blotted away with tissue paper, and diaspores were sealed in 0.25 mL tin capsules. Seeds were then dried at 80°C for 24 h and dry weight was determined. Weighing was done with a 6-place digital micro-balance and seed moisture content was expressed on a dry weight basis.

RESULTS: Initial seed moisture was similar among seed collections, averaging 4.8%. However, we found that temperature influences both the rate and the extent to which seeds hydrate before germination. There is a need to include a temperature-hydration interaction component in models of seed hydration and germination. This will promote efforts to predict seedling emergence from seedbeds subject to the fluctuating temperatures of natural environments. Research into why winterfat seeds achieve a greater degree of hydration during cold imbibition may explain both the greater freezing tolerance and superior growth that has been observed for winterfat seeds imbibed at cold temperatures.

FUTURE PLANS: This information is being used to study freezing tolerance of imbibed seeds.

[1] Department of Plant, Soil and Insect Sciences, University of Wyoming
[2] Department of Crop Science and Plant Ecology, University Saskatchewan, Saskatoon, Sask., Canada

THE INFLUENCE OF IMBIBITION TEMPERATURE ON WINTERFAT SEEDS

D.T. Booth, R.H. Abernethy[1] and R. Augustrina[1]

PROBLEM: The transition from dry to moist tissues that occurs when seeds take up water (imbibe) is a time of stress. Imbibition temperature is one stress factor and an understanding of why and how imbibition temperature influences vigor would contribute to better cultural methods.

APPROACH: We measured winterfat seedling vigor after the seeds were imbibed at temperatures between 5 and 20°C. We analyzed mitochondrial proteins from the same seed collections and we used an electron microscope to study mitochondrial structure.

RESULTS: We found that imbibition temperature may have little influence on the vigor response of fresh, healthy seed, but that it can have a significant influence on older seed. This appears largely due to age-related degradation of seed mitochondria and other organelles. From earlier studies we had hypothesized that the differential effect of imbibition temperature might be associated with mitochondrial metabolism during imbibition. That was certainly correct. We acknowledge that the research took a different path than we anticipated. We had proposed an environmental influence on mitochondrial function and therefore looked for differences in imbibition-temperature seedling-vigor responses among seed collections from different locations. We did not find those differences. For aged seed, cold imbibition appears to reduce the probability for inefficient respiration and allows time for cellular repair. Therefore we recommend imbibing winterfat seed at temperatures between 0 and 10°C as a safe standard practice. We found that storage of winterfat seed at 5°C allows seed aging to proceed such that vigor is significantly reduced after 2 or more years. Therefore we recommend winterfat seed be held at -18°C or colder for long term storage. Germination tests give little indication of potential seedling vigor. We recommend a vigor test to assess the probability for seed success.

FUTURE PLANS: We will seek funding to continue other work on the storage of native-plant seeds.

[1] Department of Plant, Soil and Insect Sciences, University of Wyoming

SEED MOISTURE AND SEED HUMIDIFICATION RELATED TO SEEDLING VIGOR OF WYOMING BIG SAGEBRUSH

Y. Bai[1], D.T. Booth and E.E. Roos[2]

PROBLEM: Restoring native shrubs to disturbed lands in a cost-efficient manner has remained a challenge to western managers of those lands. This has been true whether the land was disturbed by mining or road building, or is abandoned crop land.

APPROACH: We measured moisture and seed weight of seeds from sagebrush mother plants in the field from 5 locations in Wyoming. We also humidified seeds obtained from a commercial supplier in an attempt to improve seedling performance by manipulating seed moisture. Data for seed moisture, germination, germination rate and seedling vigor were analyzed with ANOVA.

RESULTS: When collected, seed moisture ranged from 2.3 to 9.0% for 5 collections. Germination was greatest and most rapid for collections which had the greatest seed weight. Seed moisture of the humidified collections increased most gradually at 2°C and reach the greatest level of hydration for seeds held at 10°C. Total germination, germination rate and seedling vigor were similar between treatments and controls regardless of seed moisture change; they were not affected by seed moisture content ranging from 5 to 60%. This is inconsistent with results from legume species such as soybean and snap bean. We speculate that the difference is due to seed size, since the larger seeds are known to suffer mechanical stress as tissues hydrate. We conclude that seed moisture management is not an effective management tool for this, and perhaps other small seeded species.

FUTURE PLANS: We plan further investigations into the influence of seed weight and seed moisture on the quality of Wyoming big sagebrush seed.

[1] Department of Plant, Soil and Insect Sciences, University of Wyoming
[2] USDA-ARS, National Seed Storage Laboratory, Fort Collins, CO

STRATEGIES FOR ESTABLISHING BIG SAGEBRUSH ON DISTURBED RANGELANDS

G.E. Schuman, D.T. Booth, J.K. Gores[1], R. Olson[2] and J.R. Cockrell[1]

PROBLEM: Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) is one of the most widely distributed shrubs in the region; however, reestablishing it on disturbed and degraded rangelands has proven difficult. Past experiences of direct seeding of big sagebrush has generally resulted in poor success and transplantation of nursery grown seedlings has proven labor intensive, expensive and has not always been successful. Regulatory agencies have recently been successful in getting shrub reestablishment legislation and standards approved; therefore, it will be very important to develop technology to ensure the establishment of big sagebrush on mined lands.

APPROACH: A field study was initiated in 1991 to evaluate and define effective seeding strategies for establishment of big sagebrush on disturbed rangelands. Specific objectives included the evaluation of (1) the efficacy of direct-applied topsoil for enhanced sagebrush establishment through effects of seedbank and VAM inoculum, (2) the value of various mulch types for moisture conservation and seed microsite modification, (3) the effect of competition from concurrently seeded herbaceous species on the establishment of big sagebrush, and (4) the value of initially establishing fourwing saltbush as a pioneer species for later recruitment of sagebrush.

RESULTS: Sagebrush seedling densities in 1995 showed an 8% mortality compared to the 1994 densities; however, seedling mortality did not appear to be related to treatments. Seedling growth (height) was 14 and 30% greater where no herbaceous competition existed compared to the 16 and 32 kg PLS/ha seeding rates of herbaceous grasses on the stockpiled and fresh topsoil, respectively. Reclaimed mined lands at 8 different mines were evaluated to determine the effect of seeding practices used in the early to mid 1980's. When sagebrush was included in the seed mix, sagebrush densities averaged 0.419 plants/m^2; however, when sagebrush was not included in the seed mix the density only averaged 0.003 plants/m^2. Therefore, on these 10-13 year old reclamation sites, natural recruitment has not played a significant role in the reestablishment of big sagebrush.

FUTURE PLANS: Greenhouse studies have been initiated to evaluate the effects of VAM infection of the sagebrush seedling on its water stress tolerance and survival. This project will be terminated at the end of 1996.

[1] Graduate Research Assistants, University of Wyoming
[2] Dept. Rangeland Ecology and Watershed Management, University of Wyoming

CARBON AND NITROGEN BALANCE IN A GRAZED MIXED GRASS PRAIRIE

G.E. Schuman, J.T. Manley, J.D. Reeder, R.H. Hart and J.A. Morgan

PROBLEM: Grazing strategy and stocking rate can influence the aboveground biomass components of the rangeland which may result in changes in the carbon (C) and nitrogen (N)inputs to the system. It is important to better understand the implications of grazing management on the C and N dynamics of the ecosystem so as to enable us to develop management technologies that ensures sustainability of our rangelands.

APPROACH: Pastures grazed for the past 11 years at a heavy stocking rate under three management schemes were compared to a continuous light stocking rate and to a livestock exclosure. The heavy stocking rate was evaluated under a continuous, rotationally deferred, and a short-duration rotation grazing system. Soil carbon and nitrogen dynamics were evaluated to a depth of 90 cm under the various grazing management and stocking rate treatments. Root and aboveground biomass (litter, standing dead, and live biomass) and roots and aboveground components were also evaluated for C and N to determine if these grazing treatments and stocking rates had any influence on the C and N balance of the system.

RESULTS: The amount (kg/ha) of soil C and N in the surface 30 cm was higher on the grazed treatments than on the non-grazed areas. Aboveground components generally contained greater quantities of C and N in the non-grazed exclosures than in the grazed pastures. Root biomass and quantities of C and N were not different between the grazed and ungrazed treatments. The total C and N balance of this rangeland system exhibited no significant differences regardless of grazing strategy or stocking rate. The data indicated that the grazing strategies imposed for 11 years did not affect the amount of C and N in this rangeland ecosystem. However, the data does suggest that grazing may have enhanced soil quality.

FUTURE PLANS: This phase of this research is completed and the publication reporting the C and N balance of the system is in preparation. We have expanded this study to a short-grass rangeland ecosystem that has been grazed at a heavy and light stocking rate for 54 years. Soil and vegetation component samples were collected and are being evaluated. We are also collecting canopy CO_2 exchange rates on both the mixed- and short-grass rangeland site (see other report).

EVALUATING MANAGEMENT ALTERNATIVES OF CRP LANDS

G.E. Schuman, J.D. Reeder, R.H. Hart, J. Eklund[1] and R. Gullion[2]

PROBLEM: Producers and farm program managers (NRCS and CFSA) have expressed concern and interest in alternative management systems for CRP lands prior to contract expiration that might improve the utilization of the forages produced on these lands and also increase the likelihood that these lands might stay in grass after contract expiration.

APPROACH: A field study on the Eklund farm/ranch was established in April 1994. Treatments included: (1) mowing, (2) mowing plus 67 kg N/ha, (3) burning, (4) grazing and trampling with livestock, and (5) no treatment. All treatments except the grazing were accomplished in April; the grazing was done in October. The entire 6 ha area was fenced in 1995 and grazed with 12 cow-calf pairs and a bull for 35 days (June 29-August 2, 1995). Forage production, litter, and utilization were evaluated using 1 m^2 exclosures (3 each per replicate) established in April 1995.

RESULTS: Total annual forage production was 4752, 4542, 4344, 4095, and 3899 kg/ha for the mow+N, cattle grazing/trampling, mow, burn, and control treatments; respectively in 1995. Grass production ranged from 3583 to 4199 kg/ha and alfalfa production from 286 to 761 kg/ha. Forage utilization was greatest on the mow treatment with 67% grass and 100% alfalfa utilization. The mow+N and control treatments resulted in the least utilization. The observed utilization on the control treatment was expected and is probably related to high level of standing dead plant material present from 7 years of previous growth. The low utilization of grasses (40%) on the mow+N treatment was attributed to the fact that the addition of nitrogen fertilizer increased the water use efficiency of the intermediate/smooth brome grass mixture resulting in earlier maturation and reduced palatability compared to the other treatments. The mow treatment had the greatest overall forage utilization with 100% of the alfalfa being utilized by the cattle. This project has shown that any management practice that beats down the previous years of standing dead plant material will increase forage production and forage utilization on CRP lands. This practice, whether mowing, burning or livestock grazing/trampling should be practiced during the last year of the contract to enhance forage production during the first year after contract expiration.

FUTURE PLANS: This project is complete and a report is being prepared for the cooperating agencies. Publications (technical and popular) are also planned.

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[1] Cooperating rancher, Albin, WY

[2] Rangeland Management Specialist, USDA-NRCS, Cheyenne, WY

HYDROLOGIC CHARACTERISTICS OF A NATIVE SHORTGRASS PRAIRIE

G.W. Frasier, L. Ahuja[1], F. Fielder[2], K. Close[3] and L. Weltz[4]

PROBLEM: Runoff and infiltration processes on native semiarid rangelands do not follow classical theory. Spatial variability of infiltration coupled with a network of micro-channels cause runoff patterns that are very difficult to evaluate and characterize.

APPROACH: Various rotating boom rainfall simulator studies from sites in the shortgrass rangelands of the High Plains provided basic runoff data. These data sets were used to develop techniques for runoff hydrograph analysis that are more sensitive to physical parameters that are affecting the runoff/infiltration processes of undisturbed areas. Simulator plots on the Central Plains Experimental Range, (CPER), near Nunn, CO, were selected for detailed mapping of micro-topography and characterization of spatial variability of infiltration. This data is being used to develop algorithms and models that will better characterize the runoff process.

RESULTS: Runoff hydrograph analysis from rainfall simulator plots at 11 sites in the shortgrass rangelands of the High Plains showed that biotic characteristics can have a significant impact on both the amount and rate of runoff. The impact is bounded by the interaction of the inherent infiltration rate set by the texture and porosity of the soil, soil water content, rainfall rate, and the spatial distribution of vegetation. Infiltration measurements at CPER using a tension infiltrometer show a mean unsaturated hydraulic conductivity of 20 mm/hr in bare interspace areas and 220 mm/hr in vegetative patches. Micro-topography mapping shows that the interconnected flow channels are in the low interspace areas and the vegetation located on high areas.

INTERPRETATION: Predicting infiltration and runoff from undisturbed rangelands areas can be improved with a better understanding the interactions of both the biotic and abiotic components. Past approaches have used stochastic processes to describe the systems. These approaches are not suitable for explaining the interactions of micro-topography and spatial variability of infiltration The next step is to incorporate deterministic descriptions of the parameters into an integrated common setting representative of the field conditions.

FUTURE PLANS: Studies will be conducted to further define and characterize the spatial variability of infiltration using a combination of tension infiltrometers and dye tracers.

[1] USDA-ARS, Great Plains Systems Research Unit, Ft. Collins, CO
[2] Department of Civil Engineering, Colorado State University
[3] Department of Chemical and Bioresource Engineering, Colorado State University
[4] Department of Earth Sciences, Colorado State University

GRASS: GRAZING RATES AND STRATEGIES STUDY

R.H. Hart, G.E. Schuman, J.W. Waggoner, Jr.[1] and M.A. Smith[1]

PROBLEM: Claims for the benefits of short-duration rotation grazing systems have received a great deal of publicity and some official recognition by SCS and other agencies. A study was begun in 1982 to evaluate the response of cattle, vegetation and soils to three grazing systems at three stocking rates.

APPROACH: Crossbred and Hereford steers initially weighing 260 kg grazed native range 14 June-12 October 1995. Strategies included continuous or season-long grazing; 8-paddock short-duration rotation grazing; and 24-paddock short-duration rotation grazing. Stocking rates in 1995 were 22.0 (light), 50.0 (moderate) and 66.7 (heavy) steer-days/ha. Steers were weighed every 28 days. Peak standing crop (PSC) was estimated inside 4 exclosures per pasture 24-27 July. After steers were removed from pastures on 12 October, they were moved to a contract feedlot and fed out, with treatments and strategies fed in separate pens.

FINDINGS: Peak standing crop was 1820 kg/ha, with no differences among strategies or stocking rates. Under light or moderate stocking, average daily gain was 1.14 kg, with no differences among grazing strategies. Under heavy stocking, gain was 1.04 kg under season-long grazing, 0.98 kg under 8-paddock rotation grazing, and 0.94 kg under 24-paddock rotation grazing. Gains on pasture were the same for crossbred and Hereford steers, but crossbred steers gained significantly more in the feedlot, 1.59 kg/d vs. 1.35 kg.

FUTURE PLANS: A manuscript covering the first 13 years of this study, to be submitted to Journal of Range Management, is in peer review. This study will run for at least 5 more years.

[1] Dept. of Rangeland Ecology and Watershed Management, University of Wyoming

LONG-TERM GRAZING INTENSITY STUDY, CENTRAL PLAINS EXPERIMENTAL RANGE

R.H. Hart and M. Ashby

PROBLEM: Studies of the impact of grazing intensity on steer gains and range vegetation seldom last more than a few years. Data is needed on effects over several decades.

APPROACH: In 1940, a replicated study of 3 grazing intensities was set up at the Central Plains Experimental Range. Over the years replications were dropped until a single pasture of each of 3 treatments remains. The treatments are light (L), moderate (M) and heavy (H) stocking on summer-long (May to October) grazing. In 1995, yearling heifers grazed the study 17 May-6 October. The L, M and H pastures were stocked at 15, 20 and 30 yearling heifers per 129.6 ha (320 acres), respectively, for stocking rates of 32.9, 43.8 and 65.8 heifer-d/ha. Heifers were weighed every 4 weeks.
Peak standing crop (PSC) was estimated for plots distributed over the entire area of each pasture.

FINDINGS: Average daily gains (kg) of heifers were L, 1.19; M, 0.73; and H, 0.69. Peak standing crop on the pasture plots was 1184, 988 and 727 kg/ha on L, M and H, respectively.

FUTURE PLANS: This study will be continued indefinitely. A manuscript comparing 1992-1994 botanical composition to earlier estimates, and relating gains to grazing pressure over the life of the study, is being prepared for publication. A graduate student was recruited to analyze and interpret data from other long-term studies at CPER; a manuscript is nearly ready for peer review.

GRASS CPER: GRAZING STRATEGIES ON SHORTGRASS AT CPER

R.H. Hart

PROBLEM: Large-pasture studies of the impact of grazing strategies on shortgrass prairie are needed.

APPROACH: Time-controlled rotation grazing was implemented on a 7-paddock layout, each paddock containing 65 ha (160 A). One paddock was sub-divided into 3 equal sized paddocks; these mimic a 21-paddock layout. An undivided 326-ha (800-A) pasture was grazed season-long. Three-pasture rotationally deferred grazing was implemented on three 152-ha (373-A) pastures, with grazing on one pasture per year deferred until July. Stocking rate was 1 steer/ 3.25 ha. Steers grazed from 16 May-12 October 1995, and were weighed on and off pasture.
Two exclosures were installed in each 65-ha time-controlled rotation paddock, except 4 were installed in one paddock. Three exclosures were installed in each 22-ha time-controlled rotation paddock, 5 in each rotationally deferred pasture, and 15 in the season-long pasture. Peak standing crop by species was determined by clipping in two quadrats per exclosure. A permanent 50-m transect was located in the vicinity of alternate exclosures. Basal cover was determined by 10-pin point quadrat at each meter mark along each transect.

FINDINGS: Total forage production averaged 1220 kg/ha. Production and botanical composition (not all components listed) differed among soil types but not among strategies within soil types.

Soil	Agsm	Stco	Bogr	Buda	Arlo	Disp	Spco	Oppo	Total	n	
	----------kg/ha----------										
Ascalon		2	179	166	0	45	0	41	65	1508	6
Avar		40	0	394	0	3	337	0	0	1178	12
Cascajo		8	0	189	146	95	0	35	562	1338	10
Olney	0	0	174	211	13	0	13	226	841	6	
R'hill	0	0	100	169	85	0	12	97	656	4	
Terry	0	0	202	116	47	0	21	404	1087	12	
Vona		57	124	264	5	37	14	14	246	1264	56

Average daily gains (kg) were season-long 1.10, time controlled rotation 1.16, and rotationally deferred 1.09, with no differences among strategies. Steers weighing less than 180 kg at the beginning of the season gained 23 kg more than steers weighing over 270 kg.

FUTURE PLANS: The study will be continued for at least 12 years.

GRIPES: GRAZING RANGE AND IMPROVED PASTURE EXPERIMENT ON SHORTGRASS

R.H. Hart

PROBLEM: Costs of cattle production could be reduced if the grazing season could be extended, by grazing complementary pastures in spring and/or fall, before and after the grazing season on shortgrass rangeland.

APPROACH: Two pastures of 16 ha each, containing dense, uniform stands of fourwing saltbush, were fenced off. Fifty-m transects, 2 per pasture, were established in the spring-fall saltbush pastures and in saltbush pastures with a history of summer, winter or no grazing. Data was collected on saltbush morphology and gender, and on aboveground biomass of herbaceous vegetation at 10, 30, 50, 70, and 90 cm from 10 saltbush plants on each transect. Aerial photographs were taken of each transect, to see if it was possible to determine density and cover of saltbush by this method. Twenty-one hectares each of 'Bozoisky Select' Russian wildrye and 'Hycrest' wheatgrass were seeded and fenced.

FINDINGS: Biomass samples are still being separated by species and weighed. Good stands of 'Hycrest' wheatgrass and 'Bozoisky Select' wildrye were obtained.

FUTURE PLANS: Fencing was completed and additional water tanks installed in 1995. One saltbush pasture will be stocked at 1 heifer per 2 ha (light stocking) and the other at 1 heifer per 1.6 ha (moderate stocking). Grazing will begin in April and end when regrowth of saltbush begins. Grazing will resume in the fall when cattle come off rangeland and continue until the desired degree of use on saltbush has been achieved. One 8-ha pasture (light stocking) and one 6-ha pasture (moderate stocking) of each seeded grass will be grazed both spring and fall. One 4-ha pasture (light stocking) and one 3-ha pasture (moderate stocking) of wheatgrass will be grazed in spring, followed by grazing of the same sized pastures of wildrye in the fall. Each pasture will be stocked with 5 yearling heifers. All heifers will graze shortgrass range at a moderate stocking rate in the summer. Cattle will be weighed on and off each pasture type. Production and use of each range or pasture type will be estimated by the usual methods. Changes in plant community composition will be compared on rangeland grazed season-long vs. rangeland deferred until cattle come off complementary pastures. The study will continue for 6 years. Grazing pressure-gain curves will be constructed for each pasture type, and possible interactions between grazing pressures on successive pasture types will be investigated.

MONITORING RANCH-SCALE TIME-CONTROLLED GRAZING SYSTEMS

R.H. Hart

PROBLEM: Some producers and action-agency personnel have expressed doubts about the applicability of our grazing systems research, because paddock sizes and numbers are smaller than in most ranch-scale systems.

APPROACH: In 1990, the HR Land Co. established a 47-paddock time-controlled rotation grazing system on about 2225 ha (5500 A) of rangeland (R) and crested wheatgrass (CW) pasture east of Cheyenne. We established six 50-m cover transects in three paddocks of the system and placed an exclosure near each transect. Similar transects and exclosures were placed on adjacent land, grazed season long, of the Wyoming Hereford Ranch (WHR) and Hirsig's ranch.

FINDINGS: Sufficient baseline data was collected in 1990-1994; no further data was taken in 1995.

FUTURE PLANS: Monitoring will resume on all three ranches 1998, if present management continues. We will request information on stocking rates, grazing seasons and gains from the three landowners, and share our findings with them.

NASTY: NUTRIENT ACCUMULATION NEAR STOCKWATER–TEST OF YIELD

R.H. Hart and G.E. Schuman

PROBLEM: Increased forage production and shifts in botanical composition of vegetation near stockwater tanks suggest accumulation of nitrogen as a result of increased cattle defecation near water. The accumulated nitrate might leach and raise nitrate concentrations in groundwater to unacceptable levels.

APPROACH: On the GRASS experiment and on the HR Land Co, two exclosures were placed 12.5 and 25 m from stockwater tanks which served 1, 2, 4, 8, or 16 paddocks arranged radially around the tank, and 50 m from the tank serving 16 paddocks. Average production from the exclosures used to estimate forage production and utilization on the same experiments served as checks.

FINDINGS: No consistent differences among distances from tanks or paddock numbers have been detected.

FUTURE PLANS: This study has been terminated.

MODELLING PLANT AND ANIMAL RESPONSES ON RANGE

R.H. Hart, J.D. Hanson[1] and E. Bainter[2]

PROBLEM: Models are needed which are simple enough to run on desk-top computers with inputs readily available to the livestock producer, but complete enough to aid decision-making in livestock management.

APPROACH: The original STEERISK spreadsheet was suitable for semi-arid rangeland with predominantly spring and summer precipitation in the Central Great Plains. Simple equations described the impact of management variables on the parameters of STEERISK. We tested the feasibility of using SPUR II to re-parameterize STEERISK for other rangeland locations around the western US. SPUR II appeared to over-estimate forage production on a Texas site and the influence of forage digestibility on steer intake and gains on all sites, and to under-estimate weight loss when little forage was available. Therefore we decided to use Soil Conservation Service estimates of forage production on major range sites in years of above average, average and below average production, rather than SPUR II estimates.

FINDINGS: Work on this project was halted until the 4-man NRCS technical team was in place at HPGRS. Forage production estimates for range sites in all Wyoming MLRA's were obtained. Data from GRASS and the CPER long-term grazing intensity study is being examined to determine effects of initial weight, sex and breed of cattle (see GRASS above) on the parameters of the grazing pressure x gain equations for shortgrass and mixed-grass rangelands. These effects will be incorporated in the STEERISKIER (STEERISK Intended for Every Region) spreadsheet.

FUTURE PLANS: STEERISKIER will be described in a journal article and one or more articles in producer magazines, and will be made available on diskette to interested customers.

[1] USDA-ARS, Great Plains Systems Research Unit, Ft. Collins, CO
[2] USDA-Natural Resources Conservation Service, Casper, WY

CHEW: CALF HUSBANDRY AFTER EARLY WEANING
CREW: COW RESPONSE TO EARLY WEANING

R.H. Hart, M.A. Smith[1] and J.W. Waggoner, Jr.[1]

PROBLEM: Calves usually are weaned at 180 to 210 days old, in September or October. By this time amount and quality of forage is so low that weaned calves make little or no gain, and cows are slow to regain any weight lost during nursing. If calves were weaned earlier, any reduction in weight gain below that of unweaned calves might be compensated for by gain of cows, reducing cost of winter feed for cows.

APPROACH: Two 88-ha native range pastures were stocked at 3.83 ha/cow pair (moderate SR, M), and two 72-ha range pastures at 3.13 ha/cow (heavy SR, H) on 20 Jun 1995. Each pasture contained 23 cow-calf pairs. Calves were weaned 27 September or 25 October; early-weaned calves grazed native range until 25 October, when all cattle were removed from range. Cattle were weighed every 28 days.

Forage production (PSC) on CREW and SHAG was estimated on 24-27 July by the methods described under GRASS above.

FINDINGS: Mean PSC on CREW pastures was 1820 kg/ha. Cows gained 0.64 kg/d and calves gained 0.89 kg/d, with no difference between stocking rates or weaning dates.

FUTURE PLANS: Under a SARE grant shared with the University of Wyoming, we will expand this study to include two levels of winter supplementation and two dates (March-April and May-June) of calving. Weaning dates will be September or October for early calves and November or December for late calves.

[1] Dept. of Rangeland Ecology and Watershed Management, University of Wyoming

SHAG: SUPPLEMENTING HEIFERS FOR ACCELERATED GROWTH

R.H. Hart, J.W. Waggoner, Jr.[1] and M.A. Smith[1]

PROBLEM: For successful calving as 2-year-olds, British-breed heifers should weigh about 300 kg when first bred and 400 kg at delivery of their first calf. If these weights are not achieved, first calving may be delayed, delivery may be difficult, and condition of the heifer may be so reduced that rebreeding for the second calf may be unsuccessful. All these events increase costs and reduce profits.

APPROACH: Two native range pastures of 36 ha each were stocked with 17 yearling heifers (initial weight 283 kg) each for a stocking rate of 1.89 ha/head. Pastures were grazed 20 June-13 October 1995. Heifers on one pasture were supplemented with high-energy blocks containing 15% crude protein. Supplement blocks were supplied ad lib throughout the grazing season, and supplement consumption was determined. Heifers were weighed about every 28 days. Heifers were exposed to bulls at 15 months of age. Subsequent breeding and calving performance will be related to treatment and gains.
Forage production (PSC) was estimated on 28 July by the methods described under GRASS above.

FINDINGS: Mean peak standing crop (PSC) on SHAG was 1820 kg/ha. Heifers gained 1.08 kg/d without supplement and 1.15 kg/day with supplement; the difference was significant for the only time in the 4 years of this study.

FUTURE PLANS: The study has been terminated and a manuscript will be prepared.

[1] Dept. of Rangeland Ecology and Watershed Management, University of Wyoming

UTILIZATION OF ANIMAL, MUNICIPAL, AND INDUSTRIAL WASTES ON SEMIARID RANGELANDS HYDROLOGY, SOILS, AND VEGETATION

G.E. Schuman, J.D. Reeder, G.W. Frasier and R.H. Hart

PROBLEM: Rangelands are being considered as potential sites for utilization of municipal, industrial and animal wastes. However, little information is available concerning the application of waste materials to rangelands where incorporation into the soil is not feasible, and where the vegetation consists of complex perennial grass/shrub communities rather than annual crops. Surface applications of waste products to rangelands may increase the quantity and quality of forage, and may improve water conservation. However, nutrients and heavy metals associated with the applied waste products have the potential to degrade surface and subsurface water quality, result in toxic levels of heavy metals in plant tissues, or cause undesirable shifts in plant species composition.

APPROACH: This study is being conducted at the Central Plains Experimental Range (CPER) near Nunn, CO, on short grass prairie, and at the High Plains Grasslands Research Station (HPGRS) near Cheyenne, WY, on mixed grass prairie. Treatments consisted of surface applications (23 metric tons/ha) in May, 1993, of (1) fresh feedlot cattle waste, (2) composted feedlot cattle waste, (3) phosphogypsum, (4) dried sewage sludge, and (5) control (no treatment). The soil profile and peak vegetation production have been sampled annually. Runoff water quality and quantity were evaluated with a rotating boom rainfall simulator in May and August, 1993 (see separate report).

RESULTS: Response of vegetation to applied wastes has been limited in general to the sewage sludge and composted feedlot cattle waste treatments, which both supplied high levels of N (>450 kg N/ha) and P (>250 kg P/ha). Yearly variations in precipitation patterns and amounts have controlled the response of warm- and cool- season grasses to this added N and P. In 1993, warm-season grass production increased by 38-50% (to 960-1040 kg/ha) with application of these two waste materials, while drought conditions throughout the 1994 growing season limited plant response to residual N and P from the waste amendments. In 1995, cool season grass production increased by 230-425% (to 400-750 kg/ha), and annual forb production increased by 400-490% (850-1000 kg/ha) in response to residual nutrients from the composted manure and sewage sludge. In all three years, the composted manure and sewage sludge treatments increased annual forb production by at least 400%. Long-term sampling is required to determine the persistence of desirable increases in forage quality and quantity, and undesirable increases in annual forb production due to the waste application.

FUTURE PLANS: We will sample vegetation and soil for a minimum of two more years in order to assess changes in soil properties, nutrient/heavy metal leaching, forage production/quality, and plant community composition as a result of a one-time application of these waste products..

CARBON AND NITROGEN DYNAMICS OF MARGINAL CROPLANDS RESEEDED TO GRASS COMMUNITIES

G.E. Schuman, J.D. Reeder, R.A. Bowman[1] and E.M. Taylor, Jr.

PROBLEM: A better understanding of the factors controlling soil organic matter formation and its activity is necessary to protect and restore the soil quality of marginal, highly erodible cropland. Alternative management of these lands to enable regeneration and provide economic benefit must be evaluated.

APPROACH: Field sites were established in 1987 at Egbert, Keeline and Arvada, Wyoming. Treatments included: (1) continued wheat-fallow cropping of marginal land, (2) plowed native grassland cropped to wheat-fallow, (3) grass established on long-term wheat-fallow marginal cropland, and (4) native grassland. Soil samples were collected annually from all treatments to assess soil C and N changes. Grass production data was collected from the native and seeded treatments. Wheat and straw production were also determined in the wheat cycle. This experimental design enabled calculation of C and N dynamics within the soil/plant system.

RESULTS: Soil and vegetation sampling was completed in 1995. After 60+ years of cultivation, total soil organic C and N had decreased by 25%, but the labile pool of soil organic matter had decreased by 55%. Four years after plowing native rangeland and cropping to wheat-fallow, total and labile C and N concentrations of the A horizon had decreased to the levels found in the crop lands that have been in production for 60+ years; mixing of A and B horizons by plowing in 1987 accounted for about 65% of this decrease in C and N. Loss of labile soil organic matter at the onset of cultivation was considerably more rapid than loss of total organic matter. Four years of established grass on marginal croplands increased C and N concentrations in the surface 2.5 - 7.5 cm of the soil profile; increases were more rapid in the sandy loam soils compared to the clay loam soil. Recovery of labile soil organic matter with the establishment of grasses on marginal cropland has been considerably more rapid than recovery of total organic matter. To simulate the contribution of a legume in the reestablished grass community, annual applications of N (34 kg N/ha) were made on half of each reseeded grass treatment plot. This additional N has restored N dynamics on this treatment to levels comparable to native rangeland.

FUTURE PLANS: The study will be discontinued at two sites, Keeline and Arvada, and the land returned to the owners. Study treatments will be maintained at the Egbert site, but annual soil and grass production sampling will be discontinued. Data will be summarized and manuscripts prepared.

[1] USDA-ARS, Central Plains Resources Management Research, Akron, CO

RANGELAND ALFALFA: GENETICS, PHYSIOLOGY & MANAGEMENT

J.A. Morgan, G.E. Schuman, R.H. Hart, K.H. Asay[1] and D.A. Johnson[1]

PROBLEM: Productivity of the short-grass prairie of the USA is limited primarily by water and N. Utilizing legumes in improved complementary pastures has the potential of improving forage quality and quantity for livestock production systems. There is some evidence that grazed alfalfa could become an important component of some ranching operations, although little information on management options is available, and there are only a few choices of adapted cultivars.

APPROACH: Three field experiments were begun at the USDA-ARS High Plains Grassland Research Station (HPGRS) in Cheyenne, WY in 1994. In a genetics study, 80 cultivars/accessions of alfalfa were transplanted and established into ten replicate blocks. Beginning in 1995, these plants will be grazed for several years and cultivars evaluated based primarily on long-term persistence. In a related physiology/genetics study, 15 cultivars/accessions representing much of the diversity in the genetics study were established in field plots, and will be examined in ensuing years for variability in physiological traits related to persistence. Results from this second study will help identify persistent cultivars in the genetics study, some of which will then be used in the development of a grazing tolerant cultivar for enhancing forage production in semi-arid regions of the west. In a third study, alfalfa and grass cultivars were seeded alternately in rows of variable width to evaluate optimum row spacing necessary to overcome water and nutrient competition.

RESULTS: The field experiments are in their second year at the HPGRS. The grazing study commenced in August when 24 sheep were used to graze the plots (six weeks). Two defoliation treatments were initiated in the physiology/genetics study, with half of the plots being cut twice during the summer (July 7 and Aug 25) and the other half three times (July 7, Aug. 4 & 12). Above-ground dry matter harvests were conducted in the alfalfa/grass competition study at two defoliation frequencies (twice and three times during summer) to evaluate affects of row spacing, plant type and defoliation on forage productivity and persistence.

FUTURE PLANS: Treatments and management of the plots will continue in 1996. Grazing will continue on the genetics study, and plots will begin to be evaluated for persistence and growth characteristics. Defoliation treatments will continue in the physiology/genetics study, and studies will commence to evaluate genotypic differences in below-ground remobilization of reserves. In the competition study, monitoring of growth will continue. Installation of neutron access tubes in the plots will allow us to monitor soil water of the different row spacings and species combinations. Results from all three studies will be used to develop new cultivars and management concepts for grazing alfalfa in grass mixtures in semi-arid regions of the Great Plains.

[1]USDA-ARS, Forage and Range Research, Logan, UT

GLOBAL CHANGE AND IMPLICATIONS FOR RANGELANDS

J.A. Morgan, D.R. LeCain, J.J. Read, H.W. Hunt[1] and W.G. Knight[2]

PROBLEM: Atmospheric CO_2 concentrations have been rising for more than a century, and are projected to continue rising well into the next century, with a doubling over present levels expected by mid- to late- 21st century. Work primarily with crop species has indicated increased atmospheric CO_2 concentrations can enhance plant growth through increased photosynthesis, although the magnitude of this response varies considerably with the environment and the particular species. An understanding of how prairie grasses may respond to long-term growth at elevated CO_2 will be required in order to intelligently manage rangelands.

APPROACH: Two grasses in the eastern Colorado shortgrass prairie of major importance for grazing livestock and wildlife are western wheatgrass, a cool-season (C_3) grass, and blue grama, a warm-season (C_4) grass. In an effort to anticipate how global changes will influence the productivity and species composition of the shortgrass prairie, we concluded growth chamber experiments and have begun statistical and modeling analyses to examine how CO_2 enrichment affects photosynthesis, growth and related physiological characteristics of these and other important prairie grasses.

RESULTS: Analyses of these studies confirmed our earlier growth chamber work that growth of C_3 and C_4 prairie grasses are stimulated similarly by CO_2 when grown under water-deficits. This is contrary to some reports that suggest C_3 species will respond more to CO_2 since their photosynthetic metabolism is more limited by CO_2 than that of C_4 species. Both plant water potentials and soil water contents were greater under CO_2 enrichment, a response we attribute to CO_2-induced stomatal closure and improved water use efficiency. We also found that where growth was significantly stimulate by CO_2 enrichment, plant N concentrations declined. These findings suggest that under the characteristic water-deficit conditions of the prairie, most grasses will experience increased growth, but the resultant forage may have slightly lower crude protein concentration, and thus, lower quality. Work on calibrating a plant biomass partitioning model is almost complete. When finished, we will be able to apply several different global change scenarios and predict how C_3 and C_4 range grasses will respond.

FUTURE PLANS: Modeling and growth chamber work will continue to investigate how CO_2 enrichment effects specific mechanisms (e.g., partitioning, acclimation) of plant response to CO_2. In response to recommendations of a recent program review, funding was sought and obtained (NSF) and a collaborative study undertaken with Arvin Mosier (SPN Research Unit) to build on open-top chamber facility to conduct our CO_2 enrichment studies in the field. These studies will begin in the spring of 1996 at the Central Plains Experimental Range near Nunn, CO, and will allow us to examine in a more realistic field environment how C_3 and C_4 grasses and the soils will respond to CO_2.

[1] Dept. of Rangeland Ecosystem Science, Colorado State University
[2] Front Range Community College, Ft. Collins, CO

GRAZING AND CARBON EXCHANGE ON SEMI-ARID RANGELANDS

J.A. Morgan, D.R. LeCain, G.E. Schuman, J.D. Reeder and R.H. Hart

PROBLEM: Because of a burgeoning human population and its impact on the environment, there is a critical need to better understand how human activities affect our biosphere. In rangelands, a major concern is how grazing affects the long-term sustainability of that system. A currently accepted method for evaluating an ecosystem's state and sustainability is to understand the dynamics of soil C and N, and in particular, whether organic C is in a stable state or one of flux. Yet the mechanisms underlying C and N cycling in rangelands are not understood sufficiently to formulate management recommendations for producers and other land managers.

APPROACH: Previously most progress on understanding how grazing affects soil C and N levels has focused on monitoring below-ground reserves in pastures with various histories of grazing. Our studies will combine traditional sampling of vegetation and soil C and N contents with canopy CO_2 exchange measurements (CER). CER will be monitored in pastures at the Central Plains Experimental Range (CPER, short-grass steppe) near Nunn, CO and at the High Plains Grasslands Research Station (HPGRS, mixed northern prairie) at Cheyenne, WY by two different methods. A closed-chamber approach will be utilized to characterize CER in m^2 plots along transects in heavily-, lightly- and non-grazed pastures. Because the chamber measurements are limited in terms of their ability to track seasonal aspects of CER, bowen ratio/energy balance systems will be installed at CPER and also at HPGRS to evaluate seasonal characteristics of CER.

RESULTS: In May and June of 1995, exclosure plots had higher CER than heavily- or lightly-grazed plots at CPER. These early season differences in CER were attributed to the greater proportion of cool-season, C3 species in the exclosure plots; May and June were unusually cool and wet, which should have favored photosynthesis of the cool-season, C3 species which predominated in the exclosures at that time. In contrast, the grazed plots at HPGRS had higher CER compared to the exclosures in May and June. The balance of C3/C4 species was not affected by grazing treatment at HPGRS, but leaf area index (LAI) was, with grazed plots having a higher LAI in the spring, which we believe accounted for their higher CER. These results suggest that the affects of grazing on C cycling and sequestration will depend on the particular environment and ecosystem, and that management of grasslands for productivity and sustainabilty will require knowledge of how grazing interacts with the underlying ecology of those different systems, including an understanding of how grazing affects species composition and C sequestration.

FUTURE PLANS: This experiment needs to be evaluated for several years under different environments, so plans are to continue the work for at least two more years. The bowen-ratio/energy balance equipment was installed in the fall of 1995 at CPER, and another system will be installed at HPGRS in the spring of 1996. This continual monitoring of CER in combination with the periodic chamber measurements on different grazing treatments will provide an improved insight into the seasonal and year-to-year dynamics of grassland C sequestration.

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SOIL-PLANT-NUTRIENT RESEARCH UNIT

Ronald F. Follett, Research Leader
Federal Building
301 S. Howes, Room 407
Fort Collins, CO 80522
TEL: (970) 490-8200
FAX: (970) 490-8213

FTS2000: a03rfollett@attmail.com
INTERNET: rfollett@lamar.colostate.edu

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MISSION STATEMENT

To develop and evaluate new knowledge required to efficiently manage soil, fertilizer and plant nutrients (emphasis on nitrogen) to achieve optimum crop yields, maximize farm profitability, maintain environmental quality and sustain long-term productivity.

TECHNOLOGY TRANSFER - 1995

1. Dr. Follett was visited by Dr. Javier Castellanos of Celaya, Mexico, who visited the SPN-research on groundwater nitrate in the San Luis Valley in CO. Dr. Follett has now been invited to travel to Mexico to visit several research sites and to advise on research to assist in improving ground water quality in three regions in Mexico.

2. As part of an effort to extend information concerning management of N to protect ground-water quality at the international scale, Dr. Follett served as a 'guest editor' in the preparation of a special issue of the Journal of Contaminant Hydrology. Both the authors and the audience consist of scientists from both developed and developing countries around the World.

3. As a follow-up to having helped establish the MOU with the CO state office of NRCS, Dr. Follett continues to meet and provide technology transfer input to the Joint ARS/NRCS/CASCD research committee in CO at about 6-mo intervals.

4. Dr. Follett served to help write the section concerning 'fate and transport of nitrogen in the environment' as part of the preparation of the Resource Conservation Act report that will be submitted to Congress.

5. Dr. Follett continues to provide input to the USDA Global Change Office, EPA, NRCS, and others concerning the impacts of fertilizer-N use efficiency and nitrous oxide emissions. Much of this input is in response to issues identified concerning the use of fertilizer N in the President's Climate Action Plan.

6. Dr. Hunter was invited to Battelle Pacific Northwest Labs in Richland, Washington to gave a talk on the use of vegetable oil to bioremediate high nitrate groundwater and to discuss the possibilities of developing a Cooperative Research and Development Agreement.

7. Dr. Hunter provided information and other assistance to Doris Stanley, ARS information office. Based on the information provided the NOD^+ based legume inoculum was accepted as an example of ARS developed technology and exhibited before committees in both houses of Congress in early 1995.

8. Dr. Hunter provided information on the use of vegetable oil to bioremediate high nitrate water and on the improved legume inoculum has been provided to the news media and to individuals, companies and communities. These efforts have resulted in a number of popular press news articles. A partial listing follows: "Wesson Oil to the Rescue" in Agricultural Research (July 1995); "Vegetable Oil Could Rescue Polluted Water in Wells" an ARS press release (July, 1995); "Salad oil can clean ground water, says USDA" by The Associated Press (July 18, 1995); "Feeding microbes to get rid of nitrates" in Science

News (July 15, 1995); "Oil Filters" in Tropical Fish Hobbyist (November, 1995); "Home Remedies for Pollution" in Business Week (August 7, 1995); "USDA Licenses New Soybean Inoculant" in Successful Farming (February, 1995); "USDA Administrator Tells Congress of New Product Technology" press release by United Press International (March 2, 1995); "Ag Research Described to Congress" in Farming Today (March 2, 1995); "New USDA Inoculant Gives Beans a Boost" in Soybean Digest; "Feeding microbes to get rid of nitrates" Science News (July 15, 1995); "Urbana Labs' USDA Inoculant Off to Fast Start" in Seed and Crops Industry (October, 1995).

9. Kuykendall, L.D. and W.J. Hunter. Production by Urbana Laboratories of a USDA patented NOD^+ legume inoculum begin in early 1995. Enough inoculum was sold to treat over a quarter of a million acres of soybean.

10. Dr. Hutchinson serves on the Biogenic Emissions Committee for the Emission Inventory Improvement Program sponsored by the State and Territorial Air Pollution Program Administrators, Association of Local Air Pollution Controls Officials, and the U.S.E.P.A. Its purpose is to provide agencies with the necessary tools to prepare consistent, reliable emission inventories through the adoption of standardized procedures.

11. Dr. Hutchinson was invited to assist with extending state-of-the-art technical knowledge regarding global change to the beginning graduate student level through publication of an article on "Nitrogen Cycle Interactions with Global Change Processes" in the Encyclopedia of Environmental Biology published by Academic Press.

12. Dr. Mosier is co-chair of the OECD/IPCC expert group on National Inventory Methodology for N_2O and CO_2 in Agriculture. This group provides the methodology for which countries calculate specific "greenhouse gas" emissions in accord with the Global Climate Change Convention.

13. Dr. Mosier was lead author for a section of the 1996 Intergovernmental Panel on Climate Change Report concerned with mitigating CH_4 and N_2O emissions in agriculture.

14. Dr. Mosier served a 2-week mission in Bangkok, Thailand for the International Atomic Energy Agency to advise a Thailand Department of Agriculture research section on the use of nitrogen isotopes in fertilizer nitrogen use efficiency.

^{15}N UPTAKE AND LEACHING IN A FURROW AND ALTERNATE FURROW IRRIGATION SYSTEM

J. Benjamin, L.K. Porter, H. Duke, L. Ahuja - Co-investigator: G. Butters[1]

PROBLEM: High nitrate levels in groundwater in the Great Plains has been attributed to nitrogen fertilizer applications on cropland. Alternative soil management techniques must be found to allow the use of nitrogen fertilizers on cropland and yet minimize the adverse environmental effects.

APPROACH: This research is directed at improving water management and fertilizer N placement practices that increase irrigation water efficiency and minimizing fertilizer N leaching. This ^{15}N field study is quantifying the impact of alternate, or every row irrigation and band fertilizer N placement on N availability to corn (Zea mays L.) and the movement of fertilizer N in the soil profile. The irrigation-nitrogen placement experiment was established in 1994 and continued in 1995 at the Agriculture Research, Demonstration, and Education Center (ARDEC) at Ft. Collins, Colorado. Two irrigation water placements, alternate furrow (AF) and every furrow (EF), and two ^{15}N labeled fertilizer placements, in-furrow (IF) and in-row (IR), were tested to determine plant use and nitrate leaching. Corn physiological development, biomass, total nitrogen uptake, fertilizer-N uptake, corn yield, and yield components were measured during the growing season to determine the effect of the various placement options on corn growth and the availability of the fertilizer nitrogen to the plant. Soil hydraulic properties, water contents before and after an irrigation, and soil profile distribution of the nitrate and ^{15}N at the end of the growing season to determine fertilizer-N leaching.

RESULTS: Analysis of the 1994 experimental data showed that: (1) Corn development, biomass and yield were as good with AF irrigation as with EF irrigation; (2) Fertilizer-N uptake was greater for the IR than the IF placement early in the growing season, but both were similar by the end of the growing season; (3) Total N uptake for the AF-IF treatment was about 85% of the other treatments and fertilizer-N uptake for the AF-IF treatment was about 50% of the other treatments; (4) Total N uptake and fertilizer-N uptake were similar among the EF-IR placement, EF-IF placement, and AF-IR placement by the end of the growing season; and (5) Fertilizer-N leached to > 1 m in the EF-IF treatment but < 0.5 m in the AF-IF treatment.

FUTURE PLANS: The 1995 cropping year may not provide much information on the effects of irrigation, since just after applying the labeled-N, we had six weeks of rain. It was not until the end of the growing seasons before any soil moisture differences were observed. Plant samples for 1995 are now being analyzed for total N and ^{15}N content. Soil samples for 1995 as well as soil samples from the 1994 ^{15}N placements were taken in the fall and are being analyzed for NO_3, total N and ^{15}N. As the analyses are completed we will look at ^{15}N uptake patterns from both years and also the NO_3 and ^{15}N leaching patterns of both years.

[1] Department of Soil and Crop Sciences, Colorado State University, Ft. Collins, CO.

USE OF NLEAP TO ASSESS N-USE EFFICIENCY FOR POTATOES, SMALL GRAINS, AND VEGETABLES GROWN IN THE SAN LUIS VALLEY

J.A. Delgado, and R.F. Follett. Co-investigator: J.L. Sharkoff

PROBLEM: It has been reported that nitrogen management practices in the San Luis Valley increase residual soil NO_3-N, increasing the potential NO_3-N available to leach. With approximately 147,000 hectares, agriculture is the main industry of the region. The USDA-NRCS has established the San Luis Valley Water Quality Demonstration project to promote the use of the best N management practices and minimize agricultural non-point source pollution of water resources in the valley. The USDA-ARS NLEAP model is being used by the USDA-NRCS to assess the N-use efficiency of different cropping systems in the valley and the effect on NO_3-N available to leach.

APPROACH: Data has been collected to evaluate the status of current N management practices on residual soil NO_3-N available to leach and NO_3-N leaching on 25 cooperating farms. With over 77 site-year studies, including at some sites, different organic amendments, fertilizer rates, different N-fertilizer sources, varieties, soil texture, management practices, and other treatments, this unique data set will be used to validate NLEAP across different cropping systems. The NLEAP model will be used to run two and three year model simulations which will be correlated with observed values. This will help us assess the effect of different cropping sequences and the best N management practices on NO_3-N leaching. The effect of agricultural practices such as minimum tillage, organic farming, use of slow release fertilizer, furrow irrigation, sprinkle irrigation, and others, on NO_3-N that is available to leach and N use efficiency will be evaluated. This technology transfer is shared with project cooperators, to help focus on field specific event by event management considerations, and reduce NO_3-N loading to the system.

RESULTS: Measured residual soil NO_3-N available to leach was significantly greater for lettuce systems than small grain or potatoes. Preliminary results indicate that NO_3-N leaching potential in lettuce systems was about 3.5 time greater per unit of cropland area than grain or potato. The NLEAP model has been validated for potatoes, small grains, and vegetables growing in the San Luis Valley (**Figure 1**).

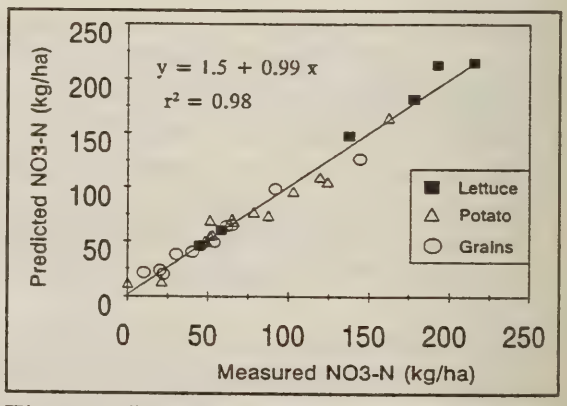

Figure 1 *Predicted vs observed residual soil NO_3-N in different cropping systems.*

FUTURE PLANS: Publications will be written and data will be used to evaluate the effect of crop rotations and N management practices on residual soil NO_3-N. This technology transfer project will continue to be shared with project cooperators.

[1]USDA-NRCS, San Luis Valley Water Quality Demonstration Project

CALIBRATION OF NLEAP FOR THE SAN LUIS VALLEY WATER QUALITY PROJECT

J.A. Delgado, R.F. Follett, and A.R. Mosier - Co-investigators: J.L. Sharkoff[1], and R.W. Lober[2]

PROBLEM: Drinking-water with high nitrate (NO_3) concentrations pose known health risks to humans and livestock. Water supplies that contain more than 10 ppm of NO_3-N are considered unfit for human consumption. The most susceptible to NO_3 health risk are infants and children under six years of age, to clinical methemoglobinemia. A recent study found well water NO_3-N concentrations as high as 75 ppm, north of the town of Center in the San Luis Valley. Previous studies of well water NO_3-N concentrations reported values in excess of 10 ppm. The combination of use of N fertilizer, high water table and sandy soils have been attributed as factors that contribute to this elevated concentration of NO_3-N in ground water. There is a growing concern about the increasing concentrations of NO_3-N in ground water.

APPROACH: In response to these concerns of higher NO_3-N concentrations in the ground water, USDA-ARS and USDA-NRCS have been using NLEAP (Nitrate Leaching and Economic Analysis Package), as a computer software package, capable of providing a rapid and efficient evaluation of the farm management practices on NO_3-N leaching. This computer simulation model is a technology transfer tool capable of generating computer outputs to identify areas where Nitrogen management practices (NMP) create NO_3-N leaching problems. By identifying the problem, the development of mitigation alternatives to improve NMP that reduce NO_3-N leaching and increase N use efficiency can be implemented.

RESULTS: Preliminary results of model simulation outputs found that the use of default parameters underestimated the residual soil NO_3-N for the top 1.5 m. Agreement between predicted *vs* observed residual soil NO_3-N improved when local parameters were used (r^2=0.86) with slope and intercept not different from 1 and 0, respectively ($P<.05$). During the last three years we have been collecting local data to be used in the model calibration. This unique data set includes N uptake indices for barley, canola, carrots, lettuce, oats, potato, spinach, winter rye, and winter wheat. Preliminary NLEAP simulations showed the potential to simulate NMP in these cropping systems.

FUTURE PLANS: This data set which includes plant parameters, NMP, soil information, irrigation practices, and climatological data will be used to calibrate the model across different cropping systems. Calibration will be done for different soil textures and agricultural practices including, minimum tillage, organic amendments, center pivot irrigation, furrow irrigation, use of slow release fertilizers, and other practices conducted in the valley. Data from the calibration of NLEAP for these different crops and for agricultural practices in the San Luis valley will be published.

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[1] USDA-NRCS, San Luis Valley Water Quality Demonstration Project, Monte Vista, CO.
[2] USDOE, Richland Operations Office, Richland, WA.

USE OF WINTER COVER CROPS TO IMPROVE SOIL AND WATER QUALITY IN THE SAN LUIS VALLEY

J.A. Delgado, and R.F. Follett - Co-investigators: J.L. Sharkoff[1] R.R. Riggenbach[1] and R.T. Sparks[2]

PROBLEM: It has been reported that N management practices in the Valley increase residual soil NO_3-N, increasing the potential NO_3-N available to leach. There is a potential to use winter cover crops as a mitigation alternative to reduce NO_3-N leaching, reduce soil erosion, scavenge soil-N, return organic carbon to the soil, and provide a potential source of over-winter or early-spring grazing before fields are cropped again. There is a concern about growing these crops under high soil NO_3-N levels. Apparently, winter wheat and winter rye are capable of accumulating appreciable amounts of NO_3-N in the aboveground biomass, to levels that can be considered potentially toxic to animals. The CSU Agricultural Extension program (Stanton, 1994; Service in action No. 1610) states that on a dry weight basis, 1150-2300 ppm NO_3-N can be considered potentially toxic and > 2300 ppm are dangerous to animals, when used as the only source of feed.

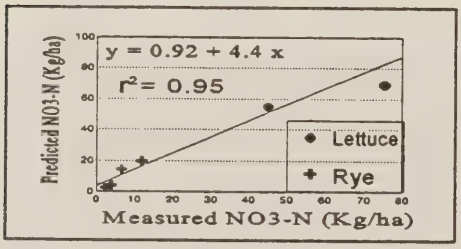

Figure 1 Predicted vs observed residual soil NO_3-N in a lettuce-winter rye cropping sequence

APPROACH: We are using the NLEAP model, to study the potential of using these crops to scavenge NO_3-N available to leach (10 year site studies). The effect of these winter cover crops on soil and water quality, and the effect of residual soil NO_3-N in NO_3-N in aboveground biomass are also studied.

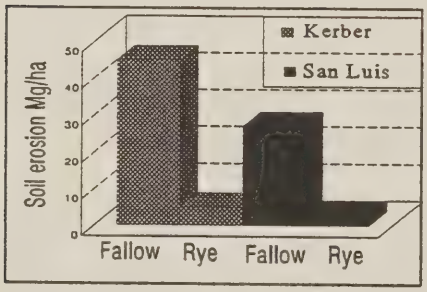

Figure 2. Potential wind erosion on a Kerber and San Luis soils under fallow or winter-cover crop

RESULTS: In the top 0.9 m of soil, rye reduced the NO_3-N available to leach (**Figure 1**). Estimated potential soil erosion by wind was reduced from 45 to 5 Mg ha^{-1} during the growth of the rye crop (**Figure 2**). Preliminary results show that winter cover crops enhance N-management, reduce soil erosion, return organic C and N to the surface soil and improve soil and water quality. However, we found that aboveground NO_3-N concentrations in rye on a dry weight basis were as high as 3352 ppm, which are potentially toxic and dangerous to animals.

FUTURE PLANS: We will continue to monitor the effect of residual soil NO_3-N in aboveground NO_3-N concentrations. We will use NLEAP to simulate the effect of these winter cover crops on water quality. A manuscript about the use of winter cover crops on water and soil quality will be published.

[1]USDA-NRCS, San Luis Valley Water Quality Demonstration Project
[2]Area Office, Alamosa, CO

USE OF CARBON DATING FOR GREAT PLAINS SOILS TO DETERMINE SOIL ORGANIC MATTER POOL SIZES AND DYNAMICS

R.F. Follett - Co-investigators: E.A. Paul[1], S. Leavitt[2], A.D. Halvorson[3], D. Lyon[4], and G. Peterson[5]

PROBLEM: Recent interest in soil organic matter (SOM) as a source-sink for carbon (C) results from assessments that a major part of the overall radiative climate forcing in global change is attributed to atmospheric carbon dioxide, of which large quantities are cycled between the atmosphere and agricultural soils. SOM and the C it contains reflect long-term effects of vegetation, soil biota, climate, parent material, time, and the disturbances by human management on ecosystem functioning. Use of carbon-14 dating techniques to determine the longevity of C storage in SOM is an emerging science; especially when applied on a regional basis.

APPROACH: Archived soil samples, collected from sites in the Great Plains of the USA in 1947/49 were obtained from storage. Field samples were also collected from Akron, CO and Sidney, NE (native grassland vs. long-term cultivation). Additional samples and/or data were obtained for Sterling, CO and Maricopa, AZ in the USA and from Waldheim and Lethbridge in Sask, Canada. Soil samples were processed by removing recent plant material. Acid hydrolysis on 1- to 3-g of soil sample was by refluxing in 6N HCl for 18h to obtain a resistant SOM fraction (hydrolysis residue) that remained after soluble materials were separated. Carbon age was measured on both hydrolysis residue and the processed soil. Soil-C age, based upon ^{14}C activity, was determined on a tandem-accelerator mass spectrometer at the Univ. of AZ.

RESULTS: Latitude did not affect ^{14}C age; it strongly influenced SOM content. Cultivation resulted in lower C content and decreases in the percent modern C equivalent to an increase of 900 yr in ^{14}C age. The effect of depth was consistent and striking. The 10 to 20 cm depths were 1200 yr older than the 0 to 10 cm depth for both cultivated and native sites. The applicability of ^{14}C dating, in conjunction with acid hydrolysis, of the soils is demonstrated. The percent of nonhydrolyzable C and its mean residence time identifies the amount and turnover rate of the resistant soil C. This information is used in conjunction with data from extended mineralization studies to analytically determine the pools and fluxes of SOM. This approach provides information on soil pedogenesis and analytically establishes pool size and flux rates of the resistant soil organic C for modeling purposes. Resistant SOM fractions were observed to be so old that; although of great importance from a soil-structure and nutrient, water and pesticide absorption standpoint; likely, play only a small role in nutrient

FUTURE PLANS: This work will be submitted for publication and additional site studies are planned that will more thoroughly consider the effects of soil depth on the MRT of soil-C.

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[1]Crop & Soil Sciences, MI State. Univ., [2]Laboratory of Tree Ring Res., Univ. of AZ, [3]ARS, Mandan, ND, and [4]Panhandle Res. and Ext. Ctr., Univ. of NE, [5]Dept. of Soil and Crop Sci., CSU.

USE OF CARBON-13 ISOTOPE CONTENTS OF GREAT PLAINS SOILS AND WHEAT-FALLOW CROPPING SYSTEMS TO DETERMINE SOIL ORGANIC MATTER POOL SIZES AND DYNAMICS

R.F. Follett - Co-investigators: E. . Paul[1], S. Leavitt[2], A.D. Halvorson[3], D. Lyon[4], and G. Peterson[5]

PROBLEM: The naturally occurring ^{13}C isotope has only recently been utilized as a tracer where plants with photosynthetic pathways have occurred in a time sequence in either managed or unmanaged agroecosystems. Sufficient published information and knowledge of native plant vegetation for the North American Great Plains now exists to begin to use $^{13}C/^{12}C$ isotope ratio data as a powerful tool for studying SOM dynamics. The current strong interest in soil organic matter (SOM) as a source-sink in global carbon (C) cycling between the atmosphere and agricultural soils now makes the use of ^{13}C an important tool for studying C sequestration in soils, especially if the data obtained are combined with that from carbon dating.

APPROACH: Archived soil samples, collected in 1947/49 from native grassland sites throughout the Great Plains of the USA, were obtained from their storage site at the Northern Great Plains Research Center in Mandan, ND. Data was also obtained for soils of the Canadian prairies. Soils sampling from Akron, CO and Sidney, NE included native grassland vs. long-term wheat-fallow cultivation. Visible plant material and inorganic C was removed and the total organic-C and the $^{13}C/^{12}C$ isotope ratio of the SOM determined by C/N analyzer and mass spectrometry. Historical yield records were obtained for both the Akron, CO and the Sidney, NE locations (both long-term experimental sites) for the purpose of estimating amounts and types of crop-residue C that had been returned to the soils at both locations.

RESULTS: The $^{13}C/^{12}C$ isotope ratio of native grassland, expressed as $\delta^{13}C$, ranged from -25.2 in the Canadian prairies to -14.9 at Dalhart, TX. This range is the result of historic mixtures of cool (C_3) and warm (C_4) season plant-species and the C-signature that their respective photosynthetic pathways have imparted to the SOM. At Akron, CO and Sidney, NE; the native grassland with an inherent C-signature that resulted from a historic mixture of mostly C_4 with some C_3 species was converted to wheat-fallow. Wheat is a C_3 species with a $\delta^{13}C$ of about -26. By isotopic ratio techniques and careful measurement of the total-organic soil-C, we have calculated the contribution of small-grain (wheat) residues to the SOM now present on these sites. Estimates of C accreted into the SOM pool from small-grain crops at Akron, is 18 to 21 kg plant-residue C/kg of C accreted into the soil organic-C pool. The corresponding value at Sidney is 10 kg plant residue C/kg soil organic-C. Cultivation initially depletes near surface soil-C with deeper soil-C becoming depleted with increasing time of cultivation.

FUTURE PLANS: This work will be submitted for publication and additional site studies are planned that will more thoroughly consider the effects of soil depth on soil-C.

[1]Crop & Soil Sciences, MI State. Univ., [2]Laboratory of Tree Ring Res., Univ. of AZ, [3]ARS, Mandan, ND, and [4]Panhandle Res. and Ext. Ctr., Univ. of NE, [5]Dept. of Soil and Crop Sci., CSU.

SOIL-C STORAGE WITHIN SOIL-PROFILES OF THE HISTORICAL GRASSLANDS OF THE USA

R.F. Follett and E.G. Pruessner - Coinvestigators: J. Kimble[1] and S. Samson[1]

PROBLEM: Large reserves and the potential to sequester large amounts of carbon (C) in soils exists in the historical grasslands (HG) of the USA. These soil are important as a source-sink in global C cycling. Large areas within the HG region are converted from cropland to the Conservation Reserve Program (CRP). Research indicates that CRP enhances C sequestration, but the magnitude is uncertain as is the importance of C gains or losses at deeper soil-profile depths. Another consideration is that CRP contracts are beginning to expire; millions of hectares of CRP land may return to production. Thus, much of the C that the CRP program helped sequester is at risk to being recycled back to the atmosphere as CO_2.

APPROACH: A collaborative effort is initiated with the National Soil Survey Laboratory (NSSL) of the NRCS in Lincoln, NE to collect detailed soil-profile measurements. Use of these data, with STATSGO or other data bases, will allow estimates of soil-C storage in the HG and the influence of management (cropped vs. CRP vs. native grassland). Soils are sampled by horizon from pits ($\geq$2m depth) at sites along precipitation and temperature gradients. At each site, a separate pit is excavated for cropped, CRP, and native land use conditions. Sites are in the same map units on similar geomorphic settings, even though soil series may change because of management. Samples from each management-site combination are returned to the either Lincoln or Fort Collins analyses. Soil-physical, -mineralogical, -micromorphological, and -chemical characterization will be done by the Lincoln laboratory the Fort Collins laboratory will be responsible for collection of data on above-ground biomass, plant-species characterization, and laboratory analyses for various C-pools (including: total-organic, identifiable plant-material, particulate organic-matter, mineral- associated, and microbial biomass-C). Isotopic analyses for $^{13}C/^{12}C$ ratios and ^{14}C dating will be done on selected samples to better assess issues related to C-sequestration processes and timing.

RESULTS: Sites have been sampled in CO, NE, and IA to obtain the West to East transect and in TX and MT to obtain a South to North transect. Samples were also collected in MO with some additional shallow sampling in CO. All samples have been returned to the respective laboratories and analyses are underway. Total soil organic C (to 2 m) increases along the precipitation gradient with average amounts of 92500, 108000, and 135000 kg/ha in CO, NE, and IA, respectively. The top 10 cm of the soil profiles were the most sensitive to land management. Organic C in the top 10 cm, as a % of the total profile C within each state increases moving from cropped to CRP to native sites.

FUTURE PLANS: Field collection of samples will be resumed this coming spring. The focus at that time will be upon completing our field sampling at sites in MN and ND.

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[1]NRCS, Lincoln, NE

USE OF THE CHLOROPHYLL METER TO PREDICT N-FERTILIZER REQUIREMENTS OF WINTER WHEAT IN COLORADO

R.F. Follett, C.A. Reule, and G. McMaster - Coinvestigator: A.D. Halvorson[1]

PROBLEM: Spring application of part of the N fertilizer to dryland winter wheat may offer advantages to applying fall only N application. A major advantage of spring-N application is that it allows spring evaluation of stand and stored soil moisture before applying N fertilizer. An additional advantage is that of a shorter period of capital tie-up with spring-N application compared to fall fertilization and that spring-applied N may increase both wheat- grain yields and protein content. Measurement of leaf greenness, as an estimate of chlorophyll content, offers an opportunity to evaluate springtime crop-N status and thereby determine the need for additional fertilizer-N application without costly delays.

APPROACH: Spring vs. fall broadcast fertilizer-N applications (as ammonium nitrate) are being evaluated at rates of 0, 22, 45, 67, and 90 kg N/ha. Additionally, all combinations of split-fall and -spring N-fertilizer application (up to a total of 90 kg N/ha) are being studied. Early spring measurements are collected of chlorophyll meter readings, plant tissue to determine stem nitrate, and soil samples to 122 cm depth for mineral-N (NO_3-N and NH_4-N) when the winter wheat is at the physiological growth stage of Feekes 5.0. Immediately following this spring sampling, the fertilizer-N is applied. At harvest, grain-protein content, fall soil mineral-N, head count, and yield components (kernel- and head-weights and fertile florets/head) are measured.

RESULTS: Field sampling is complete and laboratory and data analyses are underway. Early-season plant-tissue measurements of greenness, leaf-N, stem nitrate, and leaf C/N ratio provide information about plant-N status. Of these measures, leaf C/N may have the most linear relation to chlorophyll meter readings and grain-yield potential. Chlorophyll meter readings are related to crop yield potential, but leaf C/N ratio showed a more consistent relationship within and across years. Tiller survival is significantly affected by early-season plant-N status and is important because the number of spikes per unit area is a major yield component in the Great Plains.

FUTURE PLANS: The data will be analyzed and prepared for publication.

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[1]ARS, Mandan, ND

EFFECT OF PARAQUAT ON WHEAT STRAW DECOMPOSITION

W.J. Hunter

PROBLEM: In recent years, the use of minimum-tillage and no-till; where corn, sorghum or other crops are drilled into the existing wheat stubble; have become increasingly popular in these rotations. This procedure depends upon the careful management of crop residues throughout the crop rotation. The presence of a crop residue is important in that a residue cover on the field protects the soil from erosion while increasing weed control, water infiltration, water conservation and crop yields. Reports by the Natural Resource Conservation Service have suggested that some herbicides may accelerate the breakdown of crop residue. Little information exists on the effect different herbicides have on the rate of residue decomposition.

APPROACH: Research on this project was conducted in CY-93 through 94 and reported on in those annual reports. Research efforts in CY-95 consisted of compiling the data and preparing a manuscript for publication.

RESULTS: The paraquat treatments did not influence the rate of residue decomposition.

FUTURE PLANS: No additional studies are planned with paraquat.

BIOREMEDIATION OF HIGH NITRATE WELL WATER BY THE USE OF INNOCUOUS VEGETABLE OIL

W.J. Hunter and R.F. Follett

PROBLEM: NO_3 in subsurface waters presents a health threat to both humans and farm animals. The maximum permissible level in water used for human consumption has been set at 10 ppm NO_3-N. Agriculture has contributed to this problem as nitrate has leached from irrigated farmlands and feedlots. Only about 30% of the water from the South Platte River Aquifer in northern Colorado meets the standard. This project evaluated a method for eliminating nitrate from water. This study differs from earlier ones in that innocuous vegetable oil was used to stimulate denitrification. Because oil is hydrophobic it forms droplets when injected. These droplets do not flow with the water but become trapped by the soil and form, in essence, a filter through which the water flows. Microorganisms, capable of denitrification, are naturally present in the soil and water table. The absence of a carbon source normally limits the activity of these denitrifying microorganisms. The vegetable oil provides the carbon source, allowing these organisms to utilize the nitrates presence in the water for nitrate respiration. Applications could involve the injection of oil around a well or the mixing of oil with sand and gravel to form a filter for the removal of nitrate from drinking water. Also, oil could be injected into the ground to form a barrier to contain a nitrate plume.

APPROACH: Past work demonstrated that soil columns containing vegetable oil can remove nitrate from flowing aquifer water. This study looked at oil retention on columns, microbial population in columns and column effluents, the effect of high nitrate levels on denitrification and the effect of large amounts of oil on denitrification.

FINDINGS: Columns, 2.5 x 35 cm glass tubes containing sand or aquifer soil, were pumped with water containing NO_3. When injected with 70 µl of oil 80% of the oil was recovered from the first 5 cm of the column. Up to 15.8 ml of oil could be applied to a column. Denitrification was not blocked by these large amounts of oil. Microbial populations where highest in the oil containing part of the column. Over a 12 week period CFU's in column effluents were monitored. Columns containing no oil averaged $5.6x10^5$ CFU/ml. Columns with the oil containing region located on the inlet end had $3.8x10^5$ CFU/ml. When the oil containing region was on the outlet end CFU/ml of effluent increased ten fold to $4.9x10^6$. Bioreactor studies show that large amounts of nitrate, up to 2,000 ppm can be removed by the process. Though, almost no denitrification was observed at 4,000 ppm NO_3-N.

FUTURE PLANS: Future work will be directed at expanding the data obtained in CY 95 and at preparing the data for publication.

NO, N_2O, AND CH_4 EXCHANGE DURING N TRANSFORMATIONS IN SOIL

G.L. Hutchinson - Coinvestigators: J.W. Doran[1], M.F. Vigil[2]

PROBLEM: NO, N_2O, and CH_4 are radiatively, chemically, and ecologically important trace atmospheric constituents. Microbial processes in soil are a major source of the NO and N_2O and both a source and sink for CH_4, so it is essential to understand exchange of these gases across the soil-atmosphere boundary and, if needed, to develop mitigation technologies. Short-term exchange rates of the three gases have recently been measured from several ecosystem types under a variety of soil and climatic conditions around the world, but longer-term studies that yield tenable estimates of seasonal-to-interannual exchange at a particular site are conspicuously absent from the literature. Assessing the contribution of the net soil source of each gas to its global atmospheric budget is further confounded by immense temporal and spatial variability in the exchange rates and by the apparent existence of multiple biotic and abiotic soil sources and sinks of the gases, each of which is subject to a different set of controllers.

APPROACH: Our overall goal is to capture field-measured exchange rates of the gases in terms of their basic physical, chemical, and biological controllers. Dependence of the fluxes on these controllers will be characterized in controlled laboratory soil incubation studies and then described using simulation models parameterized by variables observable across different scales.

RESULTS: We developed the structure of a process-based simulation model for describing soil-atmosphere NO and N_2O exchange and made preliminary attempts to parameterize the model using data collected from the CRP plots at the Central Great Plains Research Station and from native grassland at the Central Plains Experimental Range. The latter represent continuing year-around measurements that suggest NO emission may represent the principal control on long-term grassland N balance and productivity. In a separate study at nearby grassland sites, we found that NO emission was greater from sandy clay loam than clay sites and from C_4 compared to C_3 plant communities. In addition, we have nearly completed laboratory evaluation of the procedure (described in last year's report) that was proposed for separating nitrifier- from denitrifier-based NO and N_2O exchange in the field, and we designed and tested a new Cr_2O_3 converter for oxidizing NO to NO_2 in our luminol-based field instrument for real-time NO detection.

FUTURE PLANS: Additional field and laboratory experiments are planned to (1) improve the model's scheme for describing the dependence of NO and N_2O exchange on soil N availability, (2) develop a more effective method of including the event-driven NO and N_2O pulses described in a separate report, and (3) continue testing of the above-mentioned procedure for weighting nitrification and denitrification modules of the simulation model. Also, we will test our new Cr_2O_3 converter in a newly released model of the same instrument before publishing its description.

[1]USDA-ARS, Lincoln, Nebraska; [2]USDA-ARS, Akron, Colorado.

PERFORMANCE OF CHAMBERS FOR MEASURING TRACE GAS EXCHANGE

G.L. Hutchinson - Coinvestigators: G.P. Livingston[1], R.W. Healy[2], R.G. Striegl[2], H.K. Iyer[3]

PROBLEM: Chambers play a critical role in research concerning surface-atmosphere trace gas exchange, so understanding their performance, accuracy, and limitations is essential to properly interpret published trace gas budgets, to develop and validate trace gas exchange models, and to conduct experimental studies of trace gas exchange processes. Deployment of either a steady-state or non-steady-state chamber inherently perturbs its underlying vertical and horizontal soil gas concentration gradients, thereby altering the surface-atmosphere gas flux that the chamber was intended to measure. Failure to understand and account for that perturbation results in the potential for significant error in estimating the true trace gas flux.

APPROACH: We are using a numerical gas diffusion model to examine steady-state and non-steady-state chamber feedback processes as a function of atmospheric interfacial layer depth, chamber headspace mixing, soil transport properties, and trace gas source/sink characteristics. It differs from other models used to investigate chamber performance in that it is 3-dimensional, uses a shorter time step, and specifically includes the chamber headspace in the simulated domain. We are also developing a nonlinear regression approach to trace gas flux estimation from non-steady-state chamber concentration data that employs a recently derived analytical solution of the 1-dimensional time-dependent gas diffusion equation.

RESULTS: The simulations indicated that performance of both steady-state and non-steady-state chambers was (1) weakly dependent on pre-deployment atmospheric interfacial layer depth, (2) strongly dependent on the intensity of headspace mixing, (3) poorest when soil transport properties supported rapid gas diffusion, (4) independent of the magnitude, distribution, or kinetics of trace gas sources, and (5) better for measuring trace gas sources than sinks in soil. A chamber-induced change in air mixing processes operating near the soil surface caused either rapid enhancement or rapid suppression of the assumed pre-deployment steady-state gas exchange rate. This initial perturbation was large compared to changes that followed, and it occurred far too rapidly to be captured by conventional chamber sampling techniques. Finally, we completed SAS simulations designed to determine the sensitivity of our proposed flux estimation method to analytical precision and to the number and timing of chamber concentration observations.

FUTURE PLANS: Following publication of these results (one manuscript accepted, one submitted, one in author review, and one in preparation), we plan laboratory studies (with some field backup) to confirm and extend the simulation results.

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[1]NASA Ames Research Center, Moffett Field, CA; [2]USGS Water Resources Division, Denver, CO; [3]Colorado State University, Fort Collins, CO.

EVENT-DRIVEN PULSES OF CO_2, NO, AND N_2O EMISSIONS FROM SOIL

G.L. Hutchinson - Coinvestigator: D.C. Reicosky[1]

PROBLEM: A large pulse of CO_2, NO, and N_2O evolution often immediately follows wetting of very dry soil. The pulse is too large to be explained by water's well-defined effects on transport in soil, and its cause remains unclear. Similar pulses sometimes occur following rapid warming of soil previously exposed to near-freezing or subfreezing temperatures, following tillage of partially compacted soil, and possibly following sudden removal of other environmental limitations on microbial growth and metabolism. Emission rates during such an event may be up to 1000-fold higher than rates preceding or following the pulse, so the quantity of soil C or N lost during its brief duration may exceed the total amount emitted during the much longer period before the soil becomes predisposed to support another emissions pulse in response to the next perturbation.

APPROACH: Both experimental and modeling approaches are being used to examine the relative contributions of biological vs. physical/chemical mechanisms to each emission pulse as a function of the gas species and the pulse driver. A separate combination of field measurements and controlled laboratory soil incubation studies is designed to test the hypothesis that the biological contribution often results from decoupling consecutive reactions mediated by separate microorganisms with different sensitivities to the offending environmental limitation.

RESULTS: The pulse of NO and N_2O (but not CO_2) that followed wetting very dry soil was inhibited by nitrapyrin but not by chlorate, which are selective inhibitors of ammonium-oxidizing and nitrite-oxidizing bacteria, respectively. Denitrifying bacteria did not appear to be involved in pulse generation under the aerobic experimental conditions. Additional pulses occurred in response to subsequent wetting events only when desiccation first reduced evolution of all three gases to near zero. Pulses of the three gases that occurred in response to simulated tillage (hand mixing) in laboratory studies were not predictably related to either the intensity of disturbance or the elapsed time since the last physical disturbance, suggesting that we have not yet identified the antecedent condition that predisposes soil to support such a pulse. Preliminary studies of temperature-induced pulses have been even less predictable.

FUTURE PLANS: We will continue using selective microbial inhibitors and independent manipulation of the concentrations and transport rates of gas-phase and solution-phase reactants and products of microbial C and N transformations in soil to characterize the contributions of these and other processes to the pulse of CO_2, NO, and N_2O evolution following temperature, wetting, and physical disturbances in controlled laboratory soil incubation experiments. As time permits, and the need arises, laboratory findings will be tested in the field. Modeling studies will be used as an aid to interpreting the findings of both field and laboratory experiments.

[1]USDA-ARS, Morris, MN.

NITROGEN BIOGEOCHEMISTRY AND N GAS EMISSIONS IN THE SHORTGRASS STEPPE

A.R. Mosier - Coinvestigators: R. Martin[1], W.J. Parton[1], D.S. Ojima[1], and D.W. Valentine[1]

PROBLEM: Recent studies in grasslands have found that gaseous N losses may be a key regulator of biogeochemistry of these ecosystems. Limited results from our studies suggest that rates of N gas loss from grasslands may be the principal control on long-term grassland N balance and productivity. Along with its role in regulating primary productivity, the N cycle of terrestrial ecosystems interacts with atmospheric trace gas chemistry in important ways. Our understanding of the dynamics and magnitudes of N gas fluxes relative to the magnitude of process which regulate N turnover is inadequate to permit prediction of the long term impact of changes in land management and climate on the ecosystem.

APPROACH: From the 24 sites where trace gas studies have been conducted at the Central Plains Experimental Range six were selected with differing textures, landscape positions and management. The soil-atmosphere exchange of NO, N_2O, CH_4 and CO_2 were measured periodically, year-round throughout 1995 to assess the impact of site variables and management on annual fluxes of these gases.

RESULTS: N-fertilization of the shortgrass steppe (SGS) with either low level fertilization to increase forage production or high amounts of N in cattle urine deposition increase both NO and N_2O emissions from fertilized soils for many years after fertilization. At sites that were fertilized with about 20 kg ammonium nitrate-N ha^{-1} yr^{-1} from 1976 until 1989 NO emissions averaged 29 ug N m^{-2} hr^{-1} compared to 18 ug N m^{-2} hr^{-1} in native sites. During the same period N_2O flux averaged 4.3 and 2.3 ug N m^{-2} hr^{-1} in fertilized and native grassland, respectively. At another set of sites where about 500 kg N ha-1 of urea-N was applied in 1982 to simulate cattle urine deposition, NO flux averaged 30, compared to 12 ug N m^{-2} hr^{-1} in native plots. Over the same period N_2O flux averaged 3.7 and 1.3 ug N m^{-2} hr^{-1} in fertilized and native plots, respectively. When the effect of enhanced NO emissions with precipitation events is included in emission estimates NO emissions in native pastures constitute approximately 50% and N_2O about 5% of N input into the SGS through atmospheric deposition. Long term N-retention studies at the high N fertilization site suggest that although the N cycle is relatively tight and N losses are low the continual emissions of N-gases regulate N retention in the system.

FUTURE PLANS: Studies to further understand N biogeochemistry in the grassland as it relates to system productivity and NO, N_2O, CO_2 and CH_4 flux will continue.

Natural Resource Ecology Laboratory, Colorado State University[1]

USING FIELD FLUX MEASUREMENTS AND LABORATORY STUDIES TO DEVELOP PROCESS BASED GAS FLUX MODELS FOR N_2O AND N_2

A.R. Mosier - Coinvestigators: W.J. Parton[1], D.W. Valentine[1], D.S. Ojima[1], and A. Kulmula[2]

PROBLEM: Since it is not possible to measure gas fluxes in all soils at all times it is necessary to develop simulation models which accurately describe trace gas fluxes from a wide variety of soils and climates. Such models are needed to assess regional fluxes and assess the impact of changes in climate and land use on fluxes of trace gases.

APPROACH: Using the information collected during the past five years, from a wide variety of grassland and cropland research sites and from laboratory studies, we have developed a process based model which describe the emission of N_2O and N_2 from the soil to the atmosphere.

RESULTS: A general model was developed to simulate N_2 and N_2O (nitrous oxide) gas fluxes from nitrification and denitrification using laboratory denitrification gas flux data and field observed nitrous oxide gas fluxes from different sites. The model simulates nitrous oxide gas fluxes as a function of soil texture, soil NH_4^+ (ammonium), soil water content, soil N turnover rate, soil pH and soil temperature. Model results and observed data suggest that nitrous oxide gas fluxes are proportional to soil N turnover and that soil ammonium levels only impact nitrous oxide gas fluxes with high level of soil ammonium (> 3 ug /g). Total denitrification (N_2 plus N_2O) gas fluxes are simulated as a function of soil respiration rates, soil NO_3^-, soil water content and soil texture. N_2 :N_2O ratio is a function of soil water content, soil NO_3^- and soil respiration rates. The denitrification model was developed using laboratory data where soil water content, soil NO_3^-, and soil C availability were varied using a full factorial design. Comparison of the model results with observed field data for the denitrification submodel shows that the model simulated N_2 and N_2O gas fluxes for different soils well with r^2 equal to 0.62, and 0.75, respectively. Comparison of simulated model results with field N_2O data for several validation sites shows that the model results compare well with the observed data, r^2 =0.62. The major discrepancy is that winter denitrification events, which are important in the annual gas flux picture, were poorly simulated by the model. The model results show that approximately 14% of the N_2O fluxes for a shortgrass steppe are a result of denitrification and that this percentage ranged from 0 to 59% for different sites and years. The model results also show that soil respiration and soil texture alter the impact of soil water content on N_2 and N_2O gas fluxes from nitrification and denitrification.

FUTURE PLANS: Further refinement of these models, as a result of further laboratory, for denitrification, and field studies, and linkage to the CENTURY model will continue. Once the trace gas flux module is linked with CENTURY a set of model comparisons using the DNDC model will be conducted.

Natural Resource Ecology Laboratory , Colorado State University[1] and the Agricultural Research Center of Finland[2]

SOIL-ATMOSPHERE EXCHANGE OF CH_4, N_2O, CO_2 AND NO IN WESTERN PUERTO RICO: EFFECT OF N-FERTILIZATION AND LIMING OF AN ACIDIFIED OXISOL

A.R. Mosier and J.A. Delgado - Collaborator: M. Keller[1]

PROBLEM: The conversion of native tropical systems into agricultural uses is considered a major factor in the recent upsurge in increases in atmospheric N_2O concentration. The systems that had been studies were generally those from recent conversion. little is known about tropical systems that have been converted from forest to intensive agriculture which then were returned to relatively stable grasslands that are used for forage production. There is little information available to consider the impact of liming acid soils and N-fertilization on atmospheric trace gas constituents.

APPROACH: In 1987 plots within the ARS Isabela research station in western Puerto Rico were experimentally acidified to about pH 4 from a normal pH of 5.5-6. Plots were returned to grass and were undisturbed for several years. In 1993 we set up plots within the acidified area to determine the effect of low pH (pH remained at about 4 in 1993) on trace gas fluxes. In October 1994 a set of plots were limed to achieve pH 5.5 to 6 while other plots received no lime. In May, 1995 we conducted a study within both limed and unlimed plots to determine the effect of adding either nitrite or ammonium plus nitrification inhibitors DCD or acetylene on NO, N_2O and ammonium flux within microplots established within the lime/unlimed main plots.

RESULTS: On the short term (2-24 hr) NO emissions were not altered by liming while N_2O emissions were significantly lower in the unlimed soil. In all cases the NO emissions were 2.5 to 10 times larger than N_2O in the relatively dry (30-40% WFPS) soil. Both DCD and acetylene decreased both NO and N_2O emissions in the limed soil. In the unlimed soil acetylene inhibited both NO and N_2O emission but DCD did not. DCD either blocks a part of the nitrification pathway that acetylene does not or possibly heterotrophic nitrifiers were responsible for nitrification in the acidified oxisol. Methane uptake was not altered by liming the acidified oxisol where it is typically 4-5 times less than the pH 6 oxisol soil. In the unlimed soil neither ammonium addition nor ammonium + DCD or acetylene affected methane uptake 24-hr after application. In the limed soil both DCD and acetylene decreased CH_4 uptake, suggesting that CH_4 oxidation may be mediated by different organisms or pathways in limed and unlimed soils.

FUTURE PLANS: Studies at the sites in Puerto Rico were terminated at the end of September, 1995. Manuscripts from the data collected are to be written and the data set are being included in the U.S. Trace Gas Network data set and will be used in a regional modeling effort.

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[1]USDA/Forest Service, Rio Piedras, Puerto Rico.

^{15}N UPTAKE AND BALANCE IN A WHEAT-SORGHUM-FALLOW SEQUENCE UNDER NO-TILL IN THE SEMIARID GREAT PLAINS

L.K. Porter, R.F. Follett - Coinvestigator: A.D. Halvorson[1]

PROBLEM: No-till cropping in the semiarid Central Great Plains increases water storage during fallowing which allows farmers to use more intensive cropping sequences than the wheat-fallow system. However, these more intensive cropping systems require additional N inputs to maintain sustainable yields. There is little information regarding the dynamics and fate of applied fertilizer-N in such intensive cropping sequences. The purpose of this ^{15}N study was to provide as complete an accounting as possible of fertilizer-N dynamics (changes in the NO_3 pool, fertilizer-N uptake by the various crops, fertilizer-N carry-over affects, and mineralization and uptake of labeled N from wheat residues) in the intensive cropping sequence of winter wheat-sorghum-fallow-winter wheat.

APPROACH: A no-till dryland field experiment was conducted from 1987 to 1991 at the Central Great Plains Research Station, Akron, Colorado. The field plot design consisted of three main plots (9.14 by 12.19m) with fertilizer N treatments of 0, 56, and 112 kg ha^{-1}, replicated four times. Each main plot was divided in to eight subplots (4.57 by 3.05m) and within the subplots were established ^{15}N microplots (2.29 by 1.83m). The microplots were fertilized at the same rate as the main plots. Four microplots received $K^{15}NO_3$ (10.37 atom %) to the first wheat crop, two of these received $^{15}NO_3$ the second year to the sorghum crop and two additional new microplots received $^{15}NO_3$ to the sorghum crop. Labeled wheat residues from two of the microplots that were fertilized the first year were exchanged with non-labeled residues. After the follow period an additional non-fertilized wheat crop was used to measure ^{15}N carryover.

RESULTS: There was no detectable NO_3 leaching, but mineralization, fertilizer applications and plant uptake had dramatic affects upon the soil NO_3 pool. Both N rates increased the total N and N uptake of the above-ground biomass of the first wheat crop and the sorghum over the unamended treatment, whereas, only the highest N rate increased the total N uptake of the second wheat crop. Plant N uptake transferred the majority of the fertilizer N to above-ground biomass. Part of that above-ground biomass was harvested as grain. Crop residue deposition, immobilization, and mineralization maintained the remaining fertilizer-N in the top 60 cm of soil. Plant uptake of labeled-N from the labeled wheat residues showed that 6.5 to 8.6% of the total N content of the residues is mineralized yearly. At the end of the 4 year cropping sequence 90 and 87% of the applied fertilizer-N was accounted-for at the 56 and 112 kg N ha^{-1} rates respectively. Of this N, generally 24 to 28% remained in the soil. The 10 to 13% of the applied fertilizer-N that was unaccounted-for was probably lost by denitrification or ammonia volatilization.

FUTURE PLANS: A manuscript has been prepared and submitted to Agron. J. The reviewed manuscript has been revised and were waiting word to see if any further revision is necessary.

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[1] Northern Great Plains Research Laboratory, Mandan, ND.

FIELD ESTIMATES OF FOLIAR AMMONIA ABSORPTION UTILIZING ^{15}N NUTRIENT-SAND CULTURE

L.K. Porter, E.A . Paul[1], P.G. Harris[1], and E.D. Buenger

PROBLEM: Atmospheric processes are important in the circulation of NO_x, N_2O, and NH_3. The emission of NH_3 to and the reabsorption of NH_3 from the atmosphere by vegetation and soils has been observed both in laboratory and field experiments. At this stage of our knowledge considerably more is known about the magnitude of the NH_3 emissions in various agricultural systems than is known about NH_3 absorption by plants in various systems. Most of the information concerning plant absorption has been determined in closed laboratory chambers. Undoubtedly, the sources and sinks for atmospheric NH_3 vary for different regions, ecosystems, and agricultural systems. The primary sources of atmospheric NH_3 appear to be animal excreta, microbial decomposition of plant materials, and application of fertilizer urea and/or NH_4 salts. During the past few decades the trend, especially in the Great Plains, has been to stock cattle in large feedlots and to capture animal wastes in pits and large lagoons. Ammonia volatilized from such feedlots and waste lagoons no doubt have an important impact on local agricultural systems and the environment. The objective of this investigation was to measure under field conditions the magnitude of atmospheric NH_3 absorption by corn plants and a sorghum-sudan grass cross over an entire growing season when located at various distances from feedlots and waste lagoons.

APPROACH: Plants were grown in sand with Hogland's ^{15}N-nutrient culture in the field. In Colorado (CO) the nutrient solution was pumped onto the sand 2 times a day with an automated system. In Michigan (MI) the nutrient solution was applied by hand. Presumably the shoots and roots of the plants should have the same enrichment as the ^{15}N-nutrient. This could be altered by foliar NH_3 volatilization, but if such volatilization did occur the lighter isotope would be lost fastest and the ^{15}N abundance of the plant tissues would increase. Any decrease in ^{15}N abundance from that of the ^{15}N-nutrient would result from absorption of normal abundance atmospheric N, presumably NH_3. The plants were grown in the edge of farmer's corn fields at sites where there was no feedlots nearby or at sites at varying distances from feedlots or waste lagoons.

RESULTS: In MI 25% of the N in shoots and 21% of the N in roots of the sorghum-sudan grass cross was N derived from the atmosphere (Ndfa) for plants near a manure lagoon. For plants 1.3 km away from the manure lagoon, 14 and 16% of the total N was Ndfa for the shoots and roots, respectively. However, at a bird sanctuary and a learning center, no NH_3 source nearby, the % Ndfa varied from 5.1 to 2.8 of the total N for shoots and roots, respectively. In CO, at ARDEC, % Ndfa was 2.4, 7.9, 0, 10.3 for ear, leaves, stalk, and roots respectively. At Kersey, CO there were 3 sites 2.8, 3.9, and 5.3 km south east of a 100,000 cattle-capacity feedlot. There were slight differences due to distance from the feedlot. The site 2.8 km from the feedlot had %Ndfa of 4.5, 7.6, 3.8 and 7.6 for ear, leaves, stalk, and roots, respectively, whereas the site furthest from the feedlot had %Ndfa of 2.1, 5.1, 0, 6.0 for ear, leaves, stalk, and roots respectively.

[1]Michigan State University, E. Lansing, MI

N_2 FIXATION BY CELLULOLYTIC MICROORGANISMS

P. Scharf[1] and L.K. Porter

PROBLEM: Cellulose is the most abundant plant constituent in nature with an annual production of about $7.5*10^{10}$ tons. Cellulose products make up more than half of the materials entering U.S. municipal landfills and it is projected that the amount of cellulosic wastes to be disposed of will rise to 10^8 tons/year. It is estimated that landfill tipping fees may soon exceed $100/ton. Many agricultural and food processing wastes are primarily cellulose. Burning has been the traditional way to dispose of unwanted plant residues that could inhibit the growth of the subsequent crop, but this practice is being curtailed by law in many locations. Cellulose residues and cellulose products (largely paper) contain little or no N and are difficult to decompose. No organism higher than the fungi possess the enzymes necessary for degradation. Composting cellulose wastes may be a viable option, especially if microorganisms can be found that use the energy of the cellulose wastes to fix dinitrogen. Such organisms could potentially speed the decomposition process and increase the N content of the final product. Such nitrogen enriched product could potentially be used for mulch/fertilizer or as an animal feed.

APPROACH: The main thrust of the project is to measure N gain and mass loss from the cellulose substrate in microbial cultures sampled from a wide range of natural locations and composting facilities. The cultures were grown on N-limiting cellulose medium under oxygen levels ranging from atmospheric to anaerobic at 30 and 50°C. The cultures found to give the greatest N gains per gram of C loss will be further characterized and studied as to environmental growth characteristics and ability to fix N.

RESULTS Dr. Scharf accepted a position with the University of Missouri in April 1995, so the research on this project is rather meager. Screening microorganism for their cellulose degradation/N_2-fixing capabilities under a range of O_2 conditions has been carried out. Experiments showed that undefined mixed cultures are much more active in both processes than are pure cultures screened for their ability to grow on N-deficient cellulose media. The cellulose degradation and N_2-fixing processes with these mixed cultures occurred most rapidly with O_2 levels between 2 and 6%. Our main concern was whether such mixed cultures could work on news print. A study was conducted at with news print as the substrate at O_2 levels of 2, 6, and 20% and at temperatures of 30 and 50°C. These samples have been processed and are now being analyzed for total N and C.

FUTURE PLANS: Prepare a manuscript on an economical system for microbial incubations in non-air atmospheres. Finish the analyses on experiments already completed.

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[1]University of Missouri, Columbia, MO.

SOIL-PLANT-NUTRIENT RESEARCH UNIT

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SUGARBEET RESEARCH UNIT

Earl G. Ruppel, Research Leader
Crops Research laboratory
1701 Centre Avenue
Fort Collins, CO 80526
TEL: (970) 498-4214
FAX: (970) 482-2909

FTS2000: a03rlcrl@attmail.com
INTERNET: eruppel@lamar.colostate.edu

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CRIS PROJECT:

5402-21220-002-00D Reduction of Applied Chemical Pest Controls and Improvement of Post-Harvest Quality in Sugarbeet

MISSION STATEMENT

Utilize distinctive site environmental and disease-free characteristics and specifically developed team expertise to: develop new knowledge and adapt biotechnologies to modify host-pathogen relations that affect disease resistance, pathogenesis, and epidemiology in sugarbeet and other plant species pertinent to sugarbeet cultivation; discover new information and techniques to identify and produce genotypes exhibiting superior disease and stress tolerance and agronomic qualities; and provide new knowledge that improves production efficiency and biochemical processing characteristics of sugarbeet.

TECHNOLOGY TRANSFER - 1995

Sugarbeet Research Unit

Earl Ruppel

1. Co-authored a poster presentation at the 58th biennial meeting of the European International Institute of Sugarbeet Research in Beaune, France, June 19-21, 1995.

2. During a tour of sugarbeet production areas, sugar factories, and sugarbeet research institutions, exchanged information on sugarbeet pathology research in the U.S. with scientists in France, Morocco, and Spain, June 22 thru July 1, 1995.

3. Presented the Sugarbeet Pathology instruction to the Beet Sugar Development Foundation's Agriculture School in Alma, MI, July 1995.

4. Participated in two meetings of the Rhizomania Task Force to update sugarbeet growers and sugar company personnel on the current status of the disease in Colorado and sugar company methods for containment.

5. Several meetings with sugarbeet growers, private agricultural consultants, and sugar company agriculturists in the field to diagnose sugarbeet disease problems and means for their suppression or control. Also diagnosed diseases of sugarbeet sent to the lab from Colorado, Montana, and Idaho, and the pathogens were identified. Various control measures were prescribed when applicable.

Lee Panella

6. Attended the Western Sugar Company-Grower Joint Research Committee Annual Meeting and Research Reporting Session, Casper, WY, January 1995.

7. Presented a paper at the biennial meeting of the American Society of Sugar Beet Technologists, New Orleans, LA, 8-11 March, 1995.

8. Senior author on a poster entitled, "Use of clones in a sugarbeet improvement program" at a meeting of the Society for In Vitro Biology, Denver, CO, 20-24 May, 1995.

9. Principal author of a research presentation at the 58th biennial meeting of European International Institute of Sugarbeet Research in Beaune, France, June 19-21, 1995.

10. During a tour of sugarbeet production areas, sugar factories, and sugarbeet research institutions, exchanged information on sugarbeet genetics research in the U.S. with scientists in France, Morocco, and Spain, June 22 thru July 1, 1995.

11. Evaluated hybrids and lines for the sugarbeet industry and growers in the Beet Sugar Development Foundation curly-top disease nursery, Twin Falls, ID, 28-29 August and 18-19 September 1995.

12. Senior author on a poster entitled, "Optimizing the commercial production of sugarbeet clones *in vitro*" at the 8th annual meeting of the Colorado Institute for Research in Biotechnology, Boulder, CO, 19 September 1995.

13. Met with other scientists at the ASA meeting to discuss current research, 29-31 October 1995. Chaired the Crop Germplasm Committee Meeting.

14. Attended meetings of the Central High Plains Dry Bean and Sugarbeet Group meetings in Laramie, WY, and Fort Collins, CO, to provide expertise in the area of sugarbeet genetics.

15. Participated in meetings of the Rhizomania Task Force to provide expertise on the development of resistant cultivars for use in the Great Plains to reduce losses from this disease.

16. Developed and activated a Cooperative Research and Development Agreement (CRADA) with Summit Plant Laboratories as the private-industry partner. The CRADA is titled: "Optimized production of clonally propagated sugarbeets."

17. Several Fort Collins disease-resistant sugarbeet germplasms were provided as requested by Holly Sugar Corporation breeders. Additionally, 15 disease-resistant germplasms were requested by and sent to Dr. Mike Asher in England; 6 O-type with 6 CMS equivalent lines were requested by Dr. Adam Szreder in Poland; and 12 *Cercospora*-resistant lines were sent to Dr. Georg Koch in Germany.

Susan Martin

18. Attended the Western Sugar Company-Grower Joint Research Committee Annual Meeting and Research Reporting Session and presented a report on research she and co-workers A. W. Lenssen and L. W. Panella conducted on the mode of action of "trap crops" for the sugarbeet cyst nematode, January 1995.

19. During a tour of sugarbeet production areas, sugar factories, and sugarbeet research institutions, exchanged information on sugarbeet physiological research in the U.S. with scientists in France, Morocco, and Spain, June 22 thru July 1, 1995.

20. Presented a day of instruction on Sugarbeet Physiology to the Beet Sugar Development Foundation's Agricultural School in Alma, Michigan, July 1995.

21. Attended meetings of the Central High Plains Dry Bean and Sugarbeet Group meetings in Laramie, WY, and Fort Collins, CO, to provide expertise in the area of sugarbeet physiology.

22. By request, Dr. Martin reviewed procedures and provided information on sucrose analysis methods to researchers at Ferry-Morse Seed Company. Dr. Martin also worked with the Director of Research for Seedex Sugarbeet Seed Company to solve sucrose analytical problems at the company's research lab. Drs. Martin and Panella, at the invitation of the Western Sugar Company and three state sugarbeet growers' associations, consulted with processing staff on sampling techniques for sucrose analysis; they statistically evaluated company data, recommended additional testing, and analyzed and interpreted additional data.

1995 FIELD EVALUATIONS OF SUGARBEET FOR LEAF SPOT RESISTANCE

Earl G. Ruppel

PROBLEM: Sugarbeet leaf spot, induced by the fungus *Cercospora beticola*, is a disease of importance wherever sugarbeet is grown. Disease suppression with fungicides is expensive and environmentally hazardous. Also, in some areas, the fungus has become resistant to the most effective fungicides. Genetic resistance is the most economical and logical means of reducing losses from this disease, and our research unit has been instrumental in the development of *Cercospora*-resistant germplasms over the past 60 years. Additionally, our method of developing suitable field epiphytotics of leaf spot is utilized by commercial and research sugarbeet breeders for testing hybrids produced with our resistant materials. At the same time, commercially developed resistant materials also are submitted to our annual field leaf spot disease nurseries for an objective evaluation of their materials.

APPROACH: The Fort Collins area is relatively free of naturally occurring Cercospora leaf spot in most years; however, through artificial inoculation and the creation of subsequent humid conditions via overhead sprinkler irrigations, we can create an environment conducive to leaf spot development. Each year, four to five sugar or beet seed companies submit more than 200 lines for evaluation in replicated tests in our nursery. Additionally, our own materials developed in our germplasm improvement efforts also are evaluated. Inoculum of *C. beticola* is prepared from infected leaves gathered and air-dried the previous year. Inoculations are performed twice at a 1-week interval during the end of June and first week of July. Repeated overhead sprinkler irrigation is used to create the necessary high relative humidity for infection and, later, to help disseminate fungal spores via splashing water.

RESULTS: The 1995 leaf spot epiphytotic developed slowly at first due to cool, wet weather in spring and early summer, but higher temperatures in late July and August, coupled with our overhead sprinkling, induced a rapid disease advance during the latter part of August. On September 14, means of the resistant and susceptible internal controls were 3.9 and 5.9 (on an increasing disease scale of 0-10, where 10 = complete defoliation), respectively. Means of contributor lines ranged from 3.8-7.2.

INTERPRETATION: Our annual field leaf spot nursery provides the only objective means for commercial sugarbeet breeders to evaluate their lines and varieties for resistance to *C. beticola*. Moreover, the nursery also enables us to test lines in our germplasm enhancement efforts to increase the resistance level to this serious pathogen.

FUTURE PLANS: For several years, our leaf spot nursery was established on land (South Farm) owned by Colorado State University (CSU). CSU informed us that this land was needed for planned construction in 1996. Thus, through the Beet Sugar Development Foundation, we have secured land just south of Windsor, CO, for our 1996 nurseries.

1995 RHIZOCTONIA RESISTANCE EVALUATIONS

Earl G. Ruppel

PROBLEM: The fungus *Rhizoctonia solani* induces a serious root rot of mature sugarbeet in most production areas. Further, partially rotted roots that end up in the sugar factory impede sugar extraction. No fungicides are registered for suppressing this disease, and cultural measures are only partially effective in reducing losses. Over the past 35-40 years, we have found and developed the only source of genetic resistance to this pathogen, which sugarbeet breeders incorporate into their cultivars. Because most companies do not have the expertise or facilities for mass production of inoculum for use in establishing a disease nursery, we provide a summer field root rot nursery in which they rely on us for evaluation of their germplasm. Additionally, in many company areas, other root diseases preclude accurate assessment of resistance to *R. solani*; our experimental fields are relatively free of other disease problems.

APPROACH: We produce inoculum of *R. solani* by growing the fungus on moist barley grain. After 3 weeks, we air-dry the colonized grain, then grind it in a Wiley mill. Inoculum is applied to the crowns of 2-month-old beets in the field, and overhead sprinkler irrigation is used intermittently throughout the day for 4 days to wet the inoculum and stimulate fungal growth. Disease evaluations of replicated tests are performed at harvest in September. Besides our Unit's tests of lines being developed in our germplasm enhancement efforts, approximately 175 lines from six to seven companies also are evaluated annually in separate tests.

RESULTS: Our objective evaluations of breeders' lines have led to the development of adequate levels of resistance in several commercial cultivars. In 1995, percent healthy roots for our highly resistant and highly susceptible internal controls were 51.2 and 8.0, respectively. Most company lines yielded 0 to about 40% healthy roots, although a few entries were comparable to our resistant control.

INTERPRETATION: Our techniques for establishing an adequate disease nursery for germplasm evaluation have led to significant increases in resistance in some commercial materials. The higher levels of resistance should result in less disease and increased yields in production areas where Rhizoctonia root rot is endemic.

FUTURE PLANS: Rhizoctonia root rot incidence and severity continues to increase in several production areas. We will continue to improve resistance in our germplasms and to evaluate breeders' lines in our disease nursery. As stated in the previous report, our root rot nursery was established on land (South Farm) owned by Colorado State University (CSU). CSU informed us that this land was needed for planned construction in 1996. Thus, through the Beet Sugar Development Foundation, we have secured land just south of Windsor, CO, for our 1996 nurseries.

BIOCONTROL POTENTIAL OF A BACTERIUM FROM RHIZOCTONIA-INFECTED SUGARBEET

Earl G. Ruppel

PROBLEM: A root rot of sugarbeet induced by *Rhizoctonia solani* causes serious losses in most production areas. Genetic resistance developed in our unit usually is sufficient to produce adequate yields; however, when environmental conditions are ideal for disease development, significant yield depression can occur in some fields. Because no fungicides are registered for suppression of this disease, we continue to search for microorganisms that could prevent losses via biocontrol of the pathogen.

APPROACH: During routine isolation of *R. solani* from diseased roots, a bacterium that inhibited the fungus in culture also was isolated. The bacterium was identified by Dr. Garry Smith (USDA-ARS, Fargo, ND) as *Klebsiella*, most likely *K. planticola*. A purified culture of the bacterium was co-plated on PDA with 10 soilborne fungi of sugarbeet and with *Trichoderma harzianum*, a known biocontrol fungus of *R. solani*. Inhibition zones between fungal colonies and the bacterium were measured.

RESULTS: One-millimeter-wide inhibition zones developed between *R. solani* strain AG-2-2 (root rot isolate), *R. solani* strain AG-4 (seedling-disease isolate) and the bacterium. The greatest width of inhibition zones occurred in co-cultures of *Phoma betae* (mean = 13 mm) and *Botrytis cinerea* (mean = 6 mm) and the bacterium. No inhibition zones formed between the bacterium and the following fungi: *Fusarium solani, F. oxysporum, Aphanomyces cochlioides, Pythium aphanidermatum, Phytophthora drechsleri, Sclerotium rolfsii, or Trichoderma harzianum*.

INTERPRETATION: The greatest evidence of biocontrol potential occurred between the bacterium and the two least important pathogens of sugarbeet--*Phoma* and *Botrytis*. Thus, this bacterium is not a likely candidate for development of biocontrol strategies against serious pathogens of sugarbeet.

FUTURE PLANS: Because some inhibition of *R. solani* was demonstrated, the bacterium was tested for its effect in suppressing seedling disease induced by the fungus in soil. The bacterium had no measurable effect on damping-off caused by the pathogen; therefore, further studies with this bacterium were abandoned. Efforts will be continued to isolate other microorganisms that may prove suitable for the biocontrol of serious sugarbeet pathogens.

ISOLATION AND PATHOGENICITY OF FUNGI FROM SIX SUGARBEET SEEDLOTS

Earl G. Ruppel

PROBLEM: Sugarbeet seedling death often occurs in lab germination tests or in the field. Diverse fungi have been isolated from seed, but their association with seedling disease has not been determined.

APPROACH: Fungi were isolated from six sugarbeet seedlots produced either in Oregon seed crops, our local field isolation plots, or in greenhouse isolation cages. Seed either was surface-disinfested or not. Fungi (25 isolates) were maintained in pure culture and tested for pathogenicity by introducing them individually to sugarbeet seed via vacuum infiltration (16 isolates) and planting in pasteurized soil, or by planting in soil infested with test isolates (8 isolates) in replicated experiments in the greenhouse. Seedling survival was determined 21 days postplanting.

RESULTS: A total of 441 fungal isolates (22 genera) were obtained from the six seedlots. Seedlots produced in Oregon field plots yielded the most isolates (62-92), whereas our greenhouse seedlot produced in an isolater cage yielded only 40 isolates. Most isolates were genera that are not thought to be sugarbeet pathogens. In the test where isolates (16) were vacuum infiltrated into sugarbeet seed, 13 isolates reduced seedling survival (percent of control) from 5.9 to 37.1%. All eight isolates used to infest soil into which sugarbeet seed was planted reduced seedling survival from 15.9 to 51.1%. One isolate of *Cercospora* induced typical leaf spot when inoculated to sugarbeet foliage. When nontreated seed of each seedlot were planted in pasteurized soil, no seedling disease occurred.

INTERPRETATION: It is not clear why there was no seedling disease when nontreated seed were planted in pasteurized soil, but a varied amount of damping-off occurred in the vacuum-infiltrated or soil-infestation tests. Perhaps, it involves a concentration phenomenon whereby the seed or soil treatments provide exceedingly high concentrations of the test fungi that are capable of either causing disease directly as pathogens or indirectly by reducing emergence via competition for needed nutrients.

FUTURE PLANS: Selected isolates of seed fungi will be tested further in an attempt to elucidate reasons for the above results.

GERMPLASM DEVELOPMENTS FOR RESISTANCE TO SUGARBEET DISEASES

L. Panella, E. G. Ruppel, and R. J. Hecker (retired)

PROBLEM: Root rot and leaf spot are two serious diseases of sugarbeets caused by fungi (*Rhizoctonia solani* and *Cercospora beticola*, respectively). The diseases caused by these fungi may produce a severe reduction of yield in many sugarbeet production areas. Control measures, based on changing the method of sugarbeet production, are not adequate by themselves to manage these diseases. Often no chemicals are registered for control of these diseases, or chemical control is expensive or environmentally unsafe.

Increased levels of genetic resistance in sugarbeet varieties are needed to minimize growers' losses from these diseases.

APPROACH: Genetic information developed previously in our research program was used to produce sugarbeet plants (lines) with improved resistance to these diseases. Lines in various stages of improvement were evaluated for resistance in field tests in which the sugarbeets had been artificially inoculated to create severe disease conditions. Results of these tests were the basis of decisions about specific lines, i.e., to release them to the sugarbeet companies, to continue to further improve them, or to discard them.

Lines likely to be useful to sugarbeet companies for variety improvement were identified and released for use by company sugarbeet breeders.

FINDINGS: Lines developed in the breeding program of Dr. R. J. Hecker still are being evaluated in the field. The lines FC725, FC726, and FC728 were released in 1995. The lines were developed in our research project that has been contributed to, in kind, by the Beet Sugar Development Foundation. The newly released lines combine excellent root rot resistance with a moderate level of leaf spot resistance.

FC725, FC726, and FC728 are releases in which the beet seed industry breeders are vitally interested. These lines will help reduce some of the current crop losses.

FUTURE PLANS: At least three lines showing outstanding performance in 1995 field trials will be released in 1996. More lines will be improved and tested in 1996, and the most promising of these will be released in 1997.

BASE POPULATIONS TO DEVELOP MULTIPLE DISEASE RESISTANCE IN SUGARBEET

L. Panella

PROBLEM: Sugarbeet varieties are hybrids; each variety consists of a cross-pollination among two or three parents. In a hybrid crop, it is preferable that all of the parents contain some level of resistance to diseases prevalent in the area in which the variety is to be grown. If selection for different diseases is done in alternating generations, some of the progress made in resistance to one disease is lost while selecting for resistance to other diseases in the following generations.

Developing lines with resistance to multiple diseases is difficult in a crop improvement program.

APPROACH: By testing the progeny of individual sugarbeet roots for many diseases during one generation, plants with resistance to multiple diseases can be identified and used as parents of the next generation. The most efficient use of progeny testing is through self-pollination. In sugarbeet, which is normally not self-pollinating, there is a gene that permits self-pollination. Sugarbeet lines from the USDA-ARS breeding program at Salinas, CA, which contain this gene, have been crossed with some of the USDA-ARS Fort Collins lines most resistant to root rot and leaf spot. The Salinas lines also contain a broad spectrum of resistance to diseases of importance in California as well as other sugarbeet production areas.

Progeny testing helps solve the problem of selecting lines with resistance to multiple diseases.

FINDINGS: Four populations that combined the lines from the USDA-ARS programs were grown in 1995.

These populations will be the sources from which lines having multiple disease resistance and high yield can be selected and released to the sugarbeet seed industry after thorough testing.

FUTURE PLANS: From these "source populations", monogerm and multigerm lines will be developed. These lines will provided combinations of resistance to some of the most destructive sugarbeet diseases, including: root rot, leaf spot, curly top, and rhizomania. These populations, together with the materials from the USDA-ARS breeding program in Fort Collins and Dr. Smith's USDA-ARS leaf spot breeding program in Fargo, will form the basis of new breeding projects for resistance to multiple diseases. They also will contain strong laboratory components that will focus on understanding the genetics of the sugarbeet and disease pathogen interaction.

BREEDING FOR CERCOSPORA/CURLY TOP RESISTANCE

L. Panella & G. A. Smith[1]

PROBLEM: Increased resistance to leaf spot caused by the fungus, *Cercospora beticola*, continues to be an extremely important goal. If the level of resistance available in most leaf spot-resistant experimental lines were present in commercial hybrids (along with good sugar and seed yield), the need for fungicides would be greatly reduced. That continued improvement in resistance to this serious pathogen is still needed in sugarbeet lines is evident by the occurrence of leaf spot fungus strains that are resistant to our most potent fungicides. Additionally, some fungicides may be removed from the market because of their perceived or real threat to the environment. In many areas where leaf spot is a problem, the curly top virus also causes significant losses.

The objective of this program is: The development, for release to the sugarbeet seed industry, of sugarbeet lines with strong resistance to multiple diseases, especially leaf spot and the curly top virus.

APPROACH: A cross among a highly Cercospora-resistant line and commercial diploid hybrids developed by the defunct Great Western program, was made. Individual sugarbeet roots will be self-pollinated in Masonville, CO, taking advantage of self-fertility caused by that particular climate. Progeny from these roots will be tested for sucrose, resistance to Cercospora leaf spot, and resistance to the curly top virus, to identify roots with resistance to both diseases and high levels of sucrose.

A population from which to choose multigerm pollinators highly resistant to leaf spot, with good combining ability for agronomic traits is being developed.

FINDINGS: Twenty advanced breeding lines or Cercospora-resistant germplasms from Fargo were evaluated at the ARS leaf spot nursery at Ft. Collins. These lines are part of the resistant germplasm development effort at Fargo and Fort Collins.

The most promising of these lines will be released to the sugarbeet seed inustry in 1997.

FUTURE PLANS: Resistant lines from this program will be incorporated into the USDA-ARS breeding program at Fort Collins to produce sugarbeet lines with resistance to multiple diseases. Development of a resistant line generally takes 7 years. A longer time may be necessary to incorporate multiple disease resistances.

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[1]Geneticist and Research Leader, USDA-ARS Northern Crop Science Lab, Fargo, ND

GENETIC VARIATION AND PATHOGENICITY IN *RHIZOCTONIA SOLANI*

L. Panella and W. Zhang[1]

PROBLEM: Rhizoctonia root rot is a serious disease of sugarbeet caused by *Rhizoctonia solani*. However, not all strains of this fungus will attack sugarbeet. Currently, it is possible to determine if a strain of this fungus will attack sugarbeet only by testing in the greenhouse. This may take 12 to 16 weeks. Sugarbeet growers who have this fungus present in their field can plant resistant sugarbeet varieties. These varieties do not yield as high as susceptible varieties if the disease is not present. A sugarbeet grower would like to test his field in the spring and be able to quickly determine if 1) the *Rhizoctonia* fungus is present and 2) if it is present, whether it is a strain that will attack sugarbeets.

There is a need for a quick test to determine if a strain of *Rhizoctonia* is able to attack sugarbeets.

APPROACH: We are using some of the new molecular biological techniques to genetically "fingerprint" *Rhizoctonia* isolates. By comparing the same piece of DNA in each strain, we are able to develop a family tree of *Rhizoctonia* and measure how related the strains are to each other. We also can use this information to uniquely mark (genetically) each strain. We are also testing each of these strains in the greenhouse to determine if they will attack sugarbeet seedlings and roots.

Once we have determined the group of strains that attack sugarbeet, we will use the genetic information that marks these strains to devise a molecular genetic test to quickly decide if a strain can attack sugarbeets.

FINDINGS: We have used a number of different molecular techniques to try and form a family tree of the *Rhizoctonia* species. We have moved to using DNA sequence analysis because this is the most powerful molecular technique to determine how closely related organisms are. We also have completed screening of our 100 strains of *Rhizoctonia* in the greenhouse on sugarbeet seedlings.

We have been able to delineate the groups of *Rhizoctonia*, but still need the DNA fingerprinting data to better distinguish within the group that contains those strains that attack sugarbeet.

FUTURE PLANS: Greenhouse tests will be used to determine those strains of the root rot fungus that attack sugarbeet roots. The genetic analysis of the DNA sequence of a small piece of DNA from each isolate will be completed this spring. This information will be correlated, and we will begin genetically "fingerprinting" those strains that attack sugarbeets.

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[1]Colorado State University student partially funded by the Beet Sugar Development Foundation

INVESTIGATION OF SEVERAL STRAINS OF *RHIZOCTONIA SOLANI* CAPABLE OF CAUSING SEVERE ROOT ROT OF SUGARBEET

L. Panella, E.G. Ruppel, and C.E. Windels[1]

PROBLEM: Rhizoctonia root rot is a serious disease of sugarbeet caused by the fungus *Rhizoctonia solani*. Sugarbeet lines developed by the USDA-ARS program at Fort Collins have excellent resistance to the disease. In over 50 years of testing, these lines have shown resistance to all strains of *Rhizoctonia* that cause disease in sugarbeets. Strains of *Rhizoctonia* that cause severe root rot in sugarbeets also have been identified in Northern Minnesota.

Do these newly identified strains of the *Rhizoctonia* fungus 1) overcome the resistance in released sugarbeet lines, and 2) cause more severe damage than the strain we have been using to test resistant varieties?

APPROACH: Similar field tests were conducted in Crookston, MN, and Fort Collins, CO, to test five strains of *Rhizoctonia* against six resistant sugarbeet lines and one susceptible sugarbeet line. One of the *Rhizoctonia* strains has been used in Fort Collins to select lines of sugarbeet that were resistant to the root rot disease. The other four strains were newly identified strains that had caused severe root rot in sugarbeet in Minnesota.

Five strains of the *Rhizoctonia* fungus were tested in the field on six resistant and one susceptible sugarbeet line.

FINDINGS: Statistical analysis of data from the six resistant lines and five strains of *Rhizoctonia* indicated that there were no significant differences disease severity caused by the different strains of *Rhizoctonia*. Only the susceptible line (931017) had serious root rot damage from all *Rhizoctonia* strains.

Analysis of data from this test confirmed that all of the resistant varieties remained resistant to all strains of *Rhizoctonia*.

FUTURE PLANS: We will continue to collaborate with Dr. Windels at Crookston, MN, to try and better understand the ability of these strains of *Rhizoctonia* to cause severe root rot disease in sugarbeet.

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[1]Plant Pathologist, Northwest Experiment Station, University of Minnesota

DEVELOPMENT OF MOLECULAR AND BIOCHEMICAL MARKERS FOR USE IN SUGARBEET BREEDING AND GENETICS

L. Panella

PROBLEM: Genetic markers are important tools used by plant breeders to improve sugarbeet germplasm. There are many kinds of genetic markers that researchers can use.
Morphological markers, due to mutations that produce changes in the plant's appearance, have been used for a long time. Unfortunately, there are a limited number of morphological markers in one sugarbeet plant or line.

More genetic markers would allow us to better understand and analyze genetic traits in sugarbeet hybrids and populations.

APPROACH: New biological technologies have allowed researchers to develop other types of genetic markers. **Biochemical markers** are a class of genetic markers that includes enzymes produced by living organisms. There are many such enzymes (often called isozymes) in every plant, and they can be used to genetically "describe" a specific plant. **Molecular markers** allow us to compare the DNA of one organism to that of another. We can use these markers to "fingerprint" plants and fungi. There are a growing number of methods of comparing DNA. Some methods amplify a small piece of DNA (PCR); other methods are based on using common pieces of DNA to "probe" plant and fungal DNA (RFLP, Minisatellite, Microsatellite).

New types of genetic markers (biochemical and molecular) are much more frequently present in plants and often have no noticeable effect on plant vigor.

FINDINGS: We are developing a data base of isozymes (biochemical markers) that are useful for working with *Rhizoctonia solani*, which is a fungus that causes root rot in sugarbeet. We also are developing techniques to use PCR-generated markers, RFLP markers, minisatellite markers, and microsatellite markers (all different kinds of molecular genetic markers) to study the *Rhizoctonia* fungus. We also are developing and using these types of markers and (molecular genetic markers) in our sugarbeet improvement program to more efficiently produce improved sugarbeet lines.

We are developing and using biochemical and molecular genetic markers with safer and quicker analysis systems that do not require the use of radioactive chemicals.

FUTURE PLANS: We will continue to develop new techniques to better understand the genetic relationships between sugarbeet plants and organisms that cause disease so we can more quickly and efficiently produce improved sugarbeet lines for the sugarbeet seed industry and sugarbeet growers.

COOPERATIVE RESEARCH AND DEVELOPMENT AGREEMENT NO. 58-3K95-M-317 WITH SUMMIT PLANT LABORATORIES, INC.

L. Panella and C.R. Smith[1]

PROBLEM: Sugarbeet cannot normally self-pollinate. This results in each individual plant within a population being unique. Sugarbeet clones can be used to produce hybrid seed for testing, which minimizes the space needed to maintain plants undergoing testing. Clonal propagation also provides a means for maintaining important plants, such as mutants, haploids, parents for genetic studies, plant cell-culture selections, and progeny from mapping populations.

Improvement of sugarbeets, with traditional or new biotechnological methods, could be significantly enhanced through the increased availability of sugarbeet plant clones.

APPROACH: The availability of commercially produced sugarbeet clones could provide a powerful tool in the improvement of sugarbeet germplasm for public and private researchers who do not have access to the facilities necessary to produce clonal material on a research or production scale. The utilization of this clonal propagation method in sugarbeets would allow researchers to use single genotypes in replicated studies for variety development and provide a means to maintain important genotypes over time.

A Cooperative Research and Development Agreement has been entered into with Summit Plant Laboratories, Inc. of Fort Collins, CO., to optimize production of clonally propagated sugarbeets.

FINDINGS: We are able to successfully clone sugarbeet plants. They have been initiated from field-harvested stecklings and greenhouse-grown sugarbeet plants. The plants have been multiplied *in vitro* and rooted in the greenhouse. Currently, we are optimizing parameters influencing the initial introduction of a sterile explant source into culture. We are maximizing the multiplication rate of the plantlets in culture and developing the most efficient techniques to root the plantlets *in vitro* and then successfully transplant them into the greenhouse and field.

This technology is being developed as a necessary foundation for the successful achievement of other biotechnology advances, further improving the competitiveness of the U.S. sugarbeet industry.

FUTURE PLANS: Summit Plant laboratories, Inc. will serve both the ARS and private industry research and development efforts with the techniques and expertise acquired in this joint project. Large scale commercial production of clonal material would be available and affordable to public and private sugarbeet interests without the cost for specialized facilities and personnel.

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[1]C.E.O., Summit Plant Laboratories, Inc.

MODE OF ACTION OF TRAP CROPS FOR THE MANAGEMENT OF THE SUGARBEET CYST NEMATODE

S. S. Martin, J. M. Thomas II, and L. Panella

PROBLEM: The sugarbeet cyst nematode (SBCN), *Heterodera schachtii*, is an important sugarbeet pest that at present is controlled by soil fumigation or multi-year rotations. An alternative, non-chemical method of control is the cultivation of certain varieties of oil radish or yellow mustard. These plants resemble sugarbeet in causing "hatching" of SBCN cysts in the soil and in attracting juvenile nematodes into the roots. In contrast to sugarbeet, however, these "trap crops" prevent normal reproduction of the nematode. Thus, planting a trap crop reduces soil populations of SBCN cysts and the severity of disease when the field is again planted to sugarbeet. We are trying to determine how trap crop cultivars disrupt the SBCN life cycle; this information could lead to improved trap crops or to other means of SBCN control.

APPROACH: Radish and mustard cultivars that are relatively resistant and others that are susceptible to SBCN exist. We are conducting comparative analyses of the biochemistry of the two types, focusing on root exudates that may enhance hatching of SBCN cysts in the soil, and on endogenous physiological factors that may be involved in the disruption of SBCN reproduction. During the past year we added to our previous work on identification of trap crop glucosinolates, a class of special chemicals well-known for their toxicity and potential as agents of chemical interactions with other organisms. We also worked to develop methods to isolate SBCN from infested soil, to hatch cysts under controlled conditions, and to grow, nematode-inoculate, and infest trap crop plants in a medium from which fine roots can be extracted for biochemical analysis.

RESULTS: In continued work on the trap crop glucosinolates, we obtained evidence that a third major mustard glucosinolate, identified by other workers as "progoitrin" (2-hydroxy-but-3-enyl glucosinolate), probably is a chemically rearranged isomer of that compound. A minor mustard glucosinolate was partially characterized; further chemical work will be required to confirm our postulated structure. SBCN cysts were obtained from infested soil by flotation; these hatched best in the presence of 3 mM zinc chloride, and sugarbeet root extracts were relatively ineffective as "hatching factors." Numerous non-floating cysts appeared intact and turgid, but could not be induced to hatch by application of any of numerous chemical or physical treatments tested. Growing trap crop seedlings for the purpose of inoculating them with nematode juveniles in "growth pouches" was unsatisfactory due to fungal/algal contamination and poor plant growth. Trap crop growth was better in sand culture, but this method p[illegible]d major difficulties in recovering fine secondary roots for analysis.

FUTURE PLANS: Technique development will continue until we can establish heavy nematode infestations of trap crop seedlings in a suitable medium. We then will compare susceptible and resistant cultivars for biochemical characteristics related to SBCN infestation. Techniques to visualize SBCN *in situ* also may be explored.

ABIOTIC ELICITATION OF SUGARBEET PHYTOALEXINS

S. S. Martin

PROBLEM: The fungus *Cercospora beticola* Sacc. attacks leaves of sugarbeet (*Beta vulgaris* L.), producing an important disease called "Cercospora leaf spot." In response to fungal infestation, sugarbeet leaves produce flavonoid compounds that appear to be factors in resistance to the disease. Studies of the host-pathogen interaction have been hampered by an inability to determine sites of fungal attack until macroscopic necrotic lesions appear; at this point, many important biochemical interactions between host and pathogen already have occurred. It would facilitate studies of the mechanism of resistance if the sugarbeet leaf phytoalexins could be induced abiotically.

APPROACH: Application of heavy metals, physical wounding, and UV-B radiation were tested for their ability to induce phytoalexins in sugarbeet cultivars known to vary from highly susceptible to highly resistant to Cercospora leaf spot.

RESULTS: Wounding or application of droplets of dilute aqueous solutions of copper, zinc, or mercury salts to sugarbeet leaves induced phytoalexin accumulation, but were difficult to apply with reproducible results. UV-B radiation applied to leaves for a controlled time at a controlled distance from the radiation source was more reproducible, and the flavonoid profile elicited in this way appeared more complex than that accumulated under natural infection by the pathogen. Some of the compounds found in significant quantity in UV-B elicited leaves appeared to be those present in trace amounts in fungus-induced necrotic lesions. Thus, it may be possible to manipulate elicitation and post-elicitation conditions to isolate and identify compounds that could be involved in early resistance steps, or could be metabolic precursors of the known active compounds.

FUTURE PLANS: In this preliminary investigation, sugarbeet cultivars with different levels of resistance to the pathogen sometimes differed in flavonoid profile elicited. However, results were not always consistent, and additional work is needed to explore the effects of plant age, leaf age, UV-B elicitation conditions, and post-elicitation incubation conditions on the flavonoid profile obtained. Once appropriate conditions have been defined, UV-B radiation will be used to follow the time-course of flavonoid accumulation in elicited leaves, avoiding the difficulty of biological elicitation in which the site of cellular injury cannot be identified early on. Subsequently, a more detailed study will be conducted of the flavonoids elicited in leaves of susceptible vs. resistant sugarbeet cultivars.

SUGARBEET RESEARCH UNIT

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WATER MANAGEMENT RESEARCH UNIT

Dale F. Heermann, Research Leader
Agricultural Engineering Research Center
Colorado State University
Fort Collins, CO 80523
TEL: (970) 491-8511
FAX: (970 491-8247)

FTS2000: a03dfheermann@attmail.com
INTERNET: dale@lily.aerc.colostate.edu

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WATER MANAGEMENT RESEARCH UNIT

CRIS PROJECTS:

0500-00040-001-23S	Development of computer model for optimal irrigation water application
0500-00043-006-00D	Water and nitrogen management to protect ground water quality
0500-00043-006-02S	Water and nitrogen management to protect ground water quality
0500-00043-007-00D	Water and nitrogen management to protect ground water quality
5402-13000-004-00D	Irrigation technologies for sustainable farming which conserve water and protect water quality
5402-13000-004-05T	Improved irrigation management
5402-13000-004-06T	On-site interactive model for irrigation load management
5402-22000-002-00D	Computer-based weed management expert systems for irrigated crops
5402-22000-002-03S	Characterizing weed populations in Nebraska soybean fields for more efficient management
5402-22000-002-04T	Protecting water quality by scouting weed populations for efficient weed management

MISSION STATEMENT

Research emphasis is to integrate applied and basic principles to develop improved water, chemical, and alternative weed management systems and irrigation system designs. Improvements are directed toward sustainable, environmentally sound and efficient systems based on soil, water, fertility, energy, and weed ecology principles. This encompasses understanding physical and biological phenomena and developing computer simulation models and expert systems to transfer new technologies to producers, consultants, action agencies, industry, and scientists.

TECHNOLOGY TRANSFER - 1995

WATER MANAGEMENT RESEARCH UNIT

1. Bausch is a member of a standing ASAE subcommittee to develop measurement and reporting practices for automated agricultural weather stations. Development of these guidelines has broad support and participation by individuals from the ASCE Irrigation Water Requirements Committee, American Association of State Climatologists, American Meteorological Society, American Society of Agronomy, National Weather Service, USDA-ARS, US Forest Service, USDA-NRCS, and US Bureau of Reclamation.

2. Bausch and Heermann are involved with a Cooperative Research and Development Agreement with LiCor, Inc. to evaluate their three-band radiometers for real-time sensing onboard a linear move or center pivot sprinkler.

3. Buchleiter provided technical support to several Cooperative Extension agents and individual farmers who are publishing crop water use amounts and doing on-farm irrigation scheduling.

4. Buchleiter and Duke participated in the three state Central Plains Irrigation Short Course held in Garden City, Kansas, making presentations on pump maintenance and variable application of water and chemicals.

5. Duke worked with CSU Extension and Colorado Climate Center to make data from the Colorado Ag Meteorologic Network, including crop water use estimates, available over the internet and by direct satellite delivery to farmer subscribers.

6. Heermann, Buchleiter and Duke are involved in a CRADA with Valmont Industries to extend the capabilities of base station software of their monitor and control system and to develop methods of spatially varied chemical and water application.

7. Heermann participated in the Water Science and Technology Board study on the Future of Irrigation in the Face of Competing Demands, sponsored by National Academy of Science.

8. Heermann participated in an irrigation research planning session at the Missouri Branch Experime: Station at Sikeston, at the invitation of NRCS.

9. Heermann and Stetson (Lincoln, NE) developed a CRADA with Electric Power Research Institute to study prediction of peak irrigation electrical loads.

10. Schweizer presented an invitational paper at the Weed Biology, Soil Management, and New Approaches to Weeds ARS Workshop in Ames, Iowa. His main focus was on the unit's current research on developing weed bioeconomic management models.

11. Wiles and Schweizer held two sessions in Fort Collins and Fort Morgan with agricultural crop consultants to explain, demonstrate, and train these consultants on how to use the weed/corn bioeconomic model using GWM format.

12. The scientists organized and participated in several farmer and researcher oriented meetings to seek input for coordinated, relevant research programs in precision farming.

PLANT NITROGEN STATUS ESTIMATED FROM CANOPY REFLECTANCE

W.C. Bausch, H.R. Duke, and G.E. Cardon[1]

PROBLEM: Water quality issues concerning excessive nitrates in ground and surface water supplies are impacting nitrogen management in many agricultural areas. Small applications of nitrogen as needed by the crop have tremendous potential for reducing nitrate contamination of ground water. Various techniques have been developed to determine plant N status. However, these techniques are laborious, time consuming, and represent point measurements. Remote sensing can sample a plant community rather than a single plant and can rapidly assess the spatial variability that exists in a field. Leaf reflectance at various wavelengths have been correlated to leaf chlorophyll concentration; unfortunately, applications have not been developed for monitoring N status at the plant canopy level.

APPROACH: Irrigated corn with various nitrogen treatments was used to obtain reflectance data to correlate with leaf N concentration and chlorophyll measurements. Canopy reflectance was obtained in the green (G), red (R), and near-infrared (NIR) wavebands using Exotech and experimental LiCor radiometers positioned perpendicular and at an oblique angle to the crop surface. Chlorophyll measurements were made with a SPAD meter. Whole plants were removed and separated into individual leaves for N analysis to correlate with reflectance data. All measurements were taken throughout the growing season. GPS data were taken simultaneously with reflectance measurements to indicate field positions associated with the reflectance data.

RESULTS: A N Reflectance Index (NRI) was proposed that is calculated as the ratio of the NIR/G for a particular field area to the NIR/G for a reference strip in the same field. The reference strip is an area that has sufficient N fertility. Soil background influences on the NRI during early vegetative growth poses problems for nadir (0° view angle, i.e., perpendicular to crop surface) acquired data. Measurements with a radiometer positioned 15° below the horizontal (75° view angle), 1 m above the crop surface, and perpendicular to the crop row minimized soil reflectance which should improve plant N estimates at the V5 and later growth stages. Comparison of canopy reflectance obtained with the LiCor radiometer to that obtained with the Exotech radiometer indicated that canopy reflectance by the LiCor was 14% underestimated in the G, 2% overestimated in the R, and 5% underestimated in the NIR. The NIR/G calculated from LiCor reflectance was 6% less than the NIR/G from Exotech data; however, dividing by the NIR/G from the reference strip using the respective radiometer's data produced near identical NRI values.

FUTURE PLANS: Plant N determined from tissue sampling (once completely analyzed) will be correlated to the NRI values obtained from data measured at nadir and 75° to determine the most useful measurement scheme. Plant N as estimated by the NRI and associated GPS positions will be input to a GIS for spatial variability analysis and data manipulation to develop a nitrogen management scheme for applying nitrogen as needed by an irrigated corn crop via the linear move sprinkler system.

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[1]Soil and Crop Sciences, Colorado State University

CLASSIFICATION OF CORN AND WEED SEEDLINGS USING IMAGE PROCESSING AND NEURAL NETWORKS

W.C. Bausch, E.E. Schweizer, M.S. Howarth[2]

PROBLEM: Excessive herbicide use to control weeds has been the norm rather than the exception. Consequently, some of these chemicals have been detected in surface and ground water supplies. Herbicide applications would be more efficient if chemicals were applied only where weeds existed. Weed seedling identification and mapping is feasible through digital imaging, image processing and pattern recognition techniques, GPS, and GIS.

APPROACH: Corn, wild proso millet, and velvetleaf were grown in the greenhouse as well as in the field. The greenhouse was used to control growth, lighting, and minimize shadows cast by the seedlings during imaging sessions. The field study was used to include variations in lighting and shadows cast by the seedlings. Images were acquired with a 35 mm camera using color slide film which when developed was converted to digital format and stored on CD-ROM. Images were acquired during the corn growth stages when post emergence herbicides would be applied. Four size and 11 shape descriptors were evaluated temporally to determine which ones were most discriminant. Optimas, an image analysis program, was used to enhance and segment the plants from their non-plant background (soil, residue, etc.) and extract size and shape descriptors from each plant in the images. One-half of the data set (training set) was used to train a neural network (Matlab Neural Network Toolbox) to recognize plants based on descriptors extracted from the images. The other half of the data set (validation set) was used to determine classification accuracy.

RESULTS: Published enhancement techniques were refined to discern plants from non-plants. This refinement enhanced the small velvetleaf petioles so that individual leaves remained intact. Plant descriptors that best isolated the plant species consisted of area, perimeter, length, circularity, rectangularity I, and the first and second invariant moments of inertia. A neural network classifier was developed from greenhouse data using the seven descriptors as input. The final network chosen as the classifier had one hidden layer containing 20 neural units and three outputs. Classification results produced a 95 % overall accuracy for the validation data set. Corn had the lowest classification accuracy of 88 %, velvetleaf the highest accuracy of 99 %, and wild proso millet had 94 %. When field validation data were used to test the greenhouse trained classifier, the overall classification accuracy dropped to 88 %. Thus, field and greenhouse training data sets were combined to retrain the 20 neural unit network. Combined validation data sets produced an overall accuracy of 94 % from the retrained classifier.

FUTURE PLANS: This project was terminated due to lack of support personnel. Technical papers will be prepared and submitted for publication.

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[2]Atlas Pacific Inc., Pueblo, CO

IMPROVING WATER QUALITY UNDER SPRINKLER IRRIGATION WITH PRECISION FARMING

G.W. Buchleiter, H.R. Duke, D.F. Heermann, W.C. Bausch, E.E. Schweizer, R.E. Smith

PROBLEM: Both farmers and researchers recognize there is significant spatial variability of crop yields within a field. Equipment for measuring yield variations and applying variable rates of fertilizer are being commercially used primarily in rainfed agriculture. Temporal variability of rain, ET rates, plant nutrient status, weed and disease pressures, also impacts yield. Intuitively, overall field yields can be significantly increased by more intensive management of fertilizers, herbicides, pesticides, and irrigation to account for spatial and temporal variabilities within a field. Although the perceived benefits are high, identifying and quantifying the significant contributing factors to yield variability is difficult.

APPROACH: Development of an integrated system for precision farming that is reliable and economical, requires improved knowledge about the magnitude and extent of yield variability as well as the variability of various production inputs. Initial efforts are directed at assessing these variabilities to determine potential savings and to specify realistic requirements for the accuracy of data collection and the irrigation system control. Subsequent efforts include the development of a completely integrated system to collect and process large amounts of data and to make and implement decisions quickly and easily. Self-propelled sprinkler irrigation systems with computerized controls and linked to a central microcomputer appear to be an effective and economical means for delivering precision farming technology under irrigated conditions.

RESULTS: An accurate yield monitor has been mounted on a small combine for use with GPS equipment to create yield maps. Hardware equipment for variable rate application of water and chemicals has been mounted on a linear move for use in a water and nitrogen rate study.

FUTURE PLANS: Yield maps will be developed for research plots as well as for selected fields of cooperating farmers to assess the range in variability and to direct subsequent efforts in assessing variability of the production inputs. Various sensors will be mounted on either high clearance field equipment or the self-propelled irrigation system to sense variations in plant water and nutrient statuses across a field. GIS technology will be used to analyze the spatially related data and develop water and chemical application recommendations that will be translated into operational controls required by the variable rate equipment. The benefits of this system will be determined by comparing actual applications with conventional methods and using water and solute transport modeling to ascertain the fate of the water and chemicals.

DESIGN AND DEVELOPMENT OF SOFTWARE FOR COMPUTERIZED MONITOR AND CONTROL EQUIPMENT FOR SELF-PROPELLED SPRINKLERS

G.W. Buchleiter, D.F. Heermann, J. Chapman[3], R. Unruh[3], D. Mack[3]

PROBLEM: Customers having computerized monitor and control systems which operate multiple self propelled sprinklers from a single microcomputer, are demanding easier user interfaces and access to collected data to make real-time management decisions. Researchers are interested in improving the speed and effectiveness of implementing research findings about improved irrigation management practices on commercial farms.

APPROACH: A cooperative research and development agreement (CRADA) exists between USDA-ARS and Valmont Industries, a major center pivot manufacturer, to aid technology transfer. Software programming is done jointly so researchers know how to access data collected by a monitor and control system for use in decision support programs. The manufacturer recognizes the value of additional benefits from improved management that their product can provide to their customers.

RESULTS: A WINDOWS version of the base station software for controlling linear move systems was field tested at ARDEC. Enhancements were added for easier creation, editing and implementation of operational programs to variably apply water and chemicals using an auxiliary controller. Data associated with variable rate application were converted to Microsoft's Access database to improve standardization and access to data. Testing of several methods including inexpensive GPS receivers for calculating the field position of a linear move system was continued on a limited basis. A commercial software package was installed and satisfactorily tested to enable complete operation of the base station software via telephone from a remote site. Spread spectrum radios which do not require licensing to operate, were purchased as an alternative communication link between the base station and the linear move at ARDEC.

FUTURE PLANS: A low-volume, low-cost pulsing chemical application system will be mounted on the linear move and interfaced with the prototype base station software for testing and evaluation during the 1996 growing season. The CAMS panel will be upgraded to improve the speed of radio communications and the enhancements of the commercial WINDOWS base station software. Spread spectrum radios will be tested to verify that no software changes are required. Development of prototype graphical programming features will be continued with field testing and evaluation. Software development for automatically translating mapping information about variable rate application to the necessary operational controls on the CAMS panel will be initiated.

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[3]Valmont Irrigation, Inc.

REAL-TIME MANAGEMENT OF IRRIGATION SYSTEMS

H. R. Duke, G.W. Buchleiter, W.C. Bausch, D.F. Heermann, G.E. Cardon[4], D.G. Westfall[4]

PROBLEM: Work on the impact of production parameter variability on crop production and environmental degradation has concentrated on spatial variability, with little attention to temporal variability. Climatic variations and pest outbreaks require timely management decisions to minimize water and chemical inputs. Self-propelled sprinklers irrigate about ⅓ the U.S. irrigated acreage and are a unique platform for precise crop management. With appropriate controls and decision making tools, these systems can be managed to account for variation in water, fertilizer, and pesticides.

APPROACH: Current research focuses on real-time decisions at the field level rather than multi-year planning. An integrated system is being developed to: (1)reduce the difficulty of obtaining data, (2) process data quickly, (3) make appropriate recommendations, and (4) implement the producer's decision in a timely manner. Field experiments evaluate the benefit of fertilizer application in response to measured plant needs as effected by water application. Remote sensing is used to develop rapid assessment of fertility and pests. Sprinkler control software is being refined to automate implementing sensed chemical and water needs. Three nitrogen and two water treatments are imposed on plots under both a linear sprinkler irrigation system and furrow irrigation. Soil water is measured weekly and estimated by meteorologic methods daily. Crop N status is measured weekly with a chlorophyll meter and by remotely sensed reflectance to evaluate spatial and temporal variability. Chlorophyll meter readings trigger weekly N applications as required to meet crop needs.

RESULTS: A low cost GPS was evaluated to determine the position of a linear move sprinkler within 6 m, which allows sufficient accuracy for automated control. Plant chlorophyll was measured with a SPAD meter for real-time control of nitrogen application to test plots, and these readings were correlated with remote sensed canopy reflectance. In the very wet 1995 season, plots receiving all N fertilizer at preplant maintained adequate fertility until midseason, then N levels dropped below target levels. Spoonfed plots maintained fertility during the grain fill stage using the same total amount. The sprinkler control software was modified to the Windows environment and to provide positioning and control of a linear move sprinkler.

FUTURE PLANS: The water and nitrogen study will continue for 2 to 3 more years to validate an irrigation and nitrogen management model. Procedures will be developed to incorporate remotely sensed data of crop nitrogen status directly into control algorithms. Annual soil sampling to 3 meters will be used to estimate the N balance on each plot to evaluate the effectiveness of fertility treatments and water management scenarios for efficient crop use of available nitrogen.

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[4]Crop and Soil Sci. Dept., Colorado State University.

SPATIALLY AND TEMPORALLY VARIED WATER & CHEMICAL APPLICATION

H.R. Duke, G.W. Buchleiter, D.F. Heermann, W.C. Bausch, J.A. Chapman[5], R.R. Unruh[5]

PROBLEM: Producers rapidly embrace technologies to improve management, sustain productivity, and better control ag chemicals. Such technology, particularly in rainfed areas, is being driven by demand with little scientific basis. Decisions are invariably made prior to planting or layby, thus cannot account for seasonal variation. Soil properties, fertility, weeds, insects, and other pests vary both spatially and temporally within a single field. When chemicals or water are applied uniformly, some areas may receive insufficient application and others more than can be efficiently used. Excess chemical applied is subject to leaching, volatization, or other loss. Thus, there is a potential to reduce costs and environmental degradation by applying water and chemicals only when and where needed. Center pivot and linear move irrigation systems are used on 1/3 of the U.S. irrigated acreage and provide a ready mechanism of transporting both the water application system and a chemical application system. With appropriate controls, these irrigation systems can also apply water and chemicals in different amounts along the system pipeline and in the direction of travel as needed.

APPROACH: Plots have been established at CSU's ARDEC under a linear-move sprinkler system to apply two water and three fertility treatments. These randomly located plots create a spatially variable pattern of both water and fertilizer application. Remotely sensed canopy reflectance is measured from a high clearance tractor to develop methods for rapid assessment of distribution of N. Sprinkler remote controls are being modified todetermine field position and apply both water and chemicals on segments of the field irrigated by center pivot and linear move sprinklers. Methods for applying variable amounts of water are being tested, and devices are being developed and evaluated for mounting on the sprinkler system to allow site specific applicaton of chemicals.

RESULTS: Even though the soils studied appear uniform, they have a wide variation of available N. Even though preplant and sidedressed treatments were fertilized to the same N level and grain yields were equal, those plots receiving excess irrigation had an average 33 kg/ha less N remaining in the soil profile. This indicates the importance of applying the appropriate amount of water and N. Sprinkler controls and software have been modified to determine the field position and implement variable water and chemical application under the linear move sprinkler. Water application has been reliably controlled by pulsing sprinkler heads for two seasons, with uniformities of 90% measured. A unique, low cost chemical application system has been developed and tested in the laboratory.

FUTURE PLANS: Water and fertility treatments will continue on the same plots for 2 to 3 years to evaluate variable application equipment and controls. Methods will be developed to utilize remote sensed data for automated N application. Variable rate chemical application systems will be installed on the sprinkler for evaluation of precision fertilizer and herbicide applications. Non-differential GPS will be further evaluated to locate the sprinkler in the field.

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[5]Valmont Irrigation, Inc.

ON SITE INTERACTIVE MODEL FOR IRRIGATION MANAGEMENT

D.F. Heermann, L.E. Stetson, and G.W. Buchleiter

PROBLEM: Irrigation pumping is concentrated during a three- to five- month period for much of the pump-irrigated areas of the U.S. Electric powered pumping increases the peak demands of the electric utilities serving these irrigation loads whether they are wholesale of retail loads. Although pumping increases peak demands for the electric power supply system, it is also a significant part of the annual revenue for some utilities and contributes to the economies of communities in irrigated areas. Many power suppliers have begun irrigation load management programs to reduce or control these peak demands. These load control programs are based on predictions from peak demands from previous years or months. Water management research has shown that crop water consumption can be calculated and the results used to schedule irrigation systems for optimum water application. This irrigation scheduling, however, can result in more irrigation systems operating simultaneously which could increase peak power demands. The need is to develop the technology to allow the power supplier to generate the needed revenue while providing the irrigator power costs that allow sustainable and profitable operations.

APPROACH: The existing EPRI model for predicting irrigation demands will be integrated with existing ARS programs for predicting crop water needs to develop modules for an on-site interactive program to predict daily electric loads caused by irrigation. Other models, techniques, or equipment will be evaluated for use or incorporation by modules into the demand prediction program. Research on farm loads have identified rural demand components that are not irrigation related. The perceived needs of irrigators compared with actual water needs of the crops will be examined. The use of GIS systems will be explored for their usefulness in delivering the technology in a user friendly package.

RESULTS: Preliminary planning has been started and a CRADA has been established with EPRI. The decision has been made to develop customer focus groups of irrigators and select several power suppliers to be used as pilot projects as the program is being developed.

FUTURE PLANS: The actual selection of cooperators will be the first task to assure that the model is user friendly and that the necessary data for operating the model is available. The intention is to develop GIS maps of the connected load and the expected crop water use. Correlations can then be developed for predicting future peak loads ase on forecasted crop ET. Aggregating the irrigation load to higher levels depending on the partic ular wholesale rate structure and transmission network may be necessary.

DEVELOP AN EVALUATION MODEL FOR CENTER PIVOT SYSTEMS

D.F. Heermann, H.R. Duke, L. Dawson[6], and K. Admire[6]

PROBLEM: Center pivot irrigation systems now irrigate approximately 25% of the total irrigated area in the United States. Center pivot manufacturers report that sales are very high which will increase the percentage of the irrigated area under center pivots. The conversion is to reduce labor requirements and irrigate land not suitable to surface methods. Increased efficiency is needed to reduce the environmental impact from irrigation. The NRCS has the need to evaluate these systems. They currently are expending considerable effort in collecting field data for evaluating and recommending improvements. The current center pivot model appears to offer potential for decreasing the effort in evaluating these systems. A user friendly version of the simulation model provides the opportunity to evaluate the uniformity with less data collection. The model then can be used to evaluate the uniformity as well as test alternative system modifications before they are made.

APPROACH: A user friendly model will be developed for use by NRCS technicians and engineers. The model will provide for the entry of field catch can data as is now often collected for use in determining the irrigation uniformity. A pump test and inventory of the sprinkler heads, spacing, and pipe sizes of the system can serve as input to the model and provide an alternative way of evaluating the system. The adoption of low pressure systems requires an increased number of catch cans for an appropriate evaluation. This also makes it important to study the effect of start-stop of the towers which can reduce the uniformity. The first effort will be to investigate the errors introduced in the evaluation process when assuming the system is a continuous move without the start-stop of towers. The current integration technique requires extensive computation and simplifying techniques will be studied.

RESULTS: A user friendly model for Windows to use on IBM compatible personal computers has been written. A graphical interface is developed to more readily portray the information needed as the program is being used by non expert users. The data required for the simulation includes: pipe sizes, pump curve, sprinkler head spacing, sprinkler type, nozzle sizes, pattern shape, discharge coefficients, pressure regulators, and desired operating speeds.

FUTURE PLANS: The model for continuous move systems will be distributed to selected users for the evaluation of the user friendly aspects of the graphical interface for both input and output. Simulation models will be developed to study different techniques for integrating the application depth of the moving system. The current model requires excessive calculations. The intent is to add an analysis phase to the evaluation that provides specific recommendations for the irrigator when making modifications and for use in scheduling irrigations.

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[6] Natural Resource Conservation Service, USDA.

SURFACE WATER REDISTRIBUTION UNDER MOVING SPRINKLERS

D.F. Heermann, R.E. Smith, and P. Luz[7]

PROBLEM: Sprinkler irrigation systems, especially high volume, low energy types, always have the possibility of applying water at a point at a rate higher than the infiltration capacity of the soil. Center pivot systems are designed to apply the same depth along the lateral. The application rate varies with distance from the pivot and with the type of sprinklers. Low pressure sprinklers have smaller pattern radii and higher application rates than higher pressure sprinklers. When the application rate exceeds the infiltration rate, the resulting runoff can reduce the efficiency and decrease the water distribution uniformity, depending on the topography and amount and rate of runoff generated. Study of this problem requires the ability to calculate the infiltration from any application method, and model the movement of any generated surface water, where the slope of the soil may cause water to move in either or both directions down a furrow. Existing irrigation advance models are incapable of treating this more general case. Further, existing models are unable to properly treat cases where there may be a sequence of wetting and redistribution in the soil at any point. New tools are needed for the design and analysis of irrigation systems.

APPROACH: The application rate from moving systems will be simulated for the low and high pressure sprinkler patterns for input to the infiltration and surface flow models. The diffusive wave simplification of the general Saint Vennant equations for surface water flow allow for any reasonable positive slope, including flat surfaces, since the water surface slope is used rather than the bed slope. The numerical formulation can allow a negative slope as well, by using the slope sense to determine the direction of flow, and the absolute slope value within the expression itself. A robust and physically-derived infiltration model is used to solve for infiltration rates for intermittent application patterns, which includes redistribution calculations.

RESULTS: Both diked and undiked, circular and linear furrows with point source application from a center pivot have been studied. Each has its advantages: the intermittent nature of the advance of a head on a center pivot system can cause local "dry" spots in the diked case, but the undiked furrows will as expected cause an excess at the low spots of the field. An analysis of the detail needed to describe application rates under center pivots and resulting potential runoff will be made.

FUTURE PLANS: Data have been taken for variable advance rates at ARDEC, and more may be taken this year, to study both temporal and spatial variations in infiltration rates. Efforts will continue the model development with an algorithm that can determine a critical time step, to take advantage of conditions where longer time steps can be safely employed, and to prevent difficult iteration when smaller time steps are needed. An estimate of actual topography at the site of measured local application rates requires additional field data before a paper can be written. Ultimately the model will be part of a larger, GIS-based simulation tool.

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[7] Estaçào Agronomica Nacional, Quinta do Marqués, Portugal

WATER MANAGEMENT WITH SPATIAL AND TEMPORAL VARIABILITY

D.F. Heermann, M.J. Paulson[8], G.W. Buchleiter and W.C. Bausch

PROBLEM: Production agriculture has become concerned about its impact on the environment. Non-point pollution is a major factor contributing to decrease in water quality in both surface and ground water. The assumption that degradation occurs uniformly over large areas is not true. Prescription farming is an approach to reducing the chemicals in the environment practiced primarily on dry land farms. The solution to this problem under irrigated agriculture is an opportunity for the future. The systems designed for variable application of water and chemicals should reduce the environmental degradation. However, to implement this technology requires the assessment and characterization of the spatial variability. Use of geographical information systems (GIS) and global positioning systems (GPS) are tools that will allow the collection and analysis of spatial data. The layers of information collected over time will provide for analyzing the temporal variability.

APPROACH: The Agricultural Research, Demonstration and Education Center (ARDEC) at Colorado State University will provide the prototype area for developing GIS maps and collecting spatial data with sensors and GPS. The first task will be to develop the map of the area with bench mark control. Existing topographic, field physical boundaries, irrigation system and soil's data bases will be put into ARC/INFO GIS programs. Data will be collected from the current activities and procedures developed to input into the data base. The GPS will be used to position remote sensed data and other sampled data such as soil samples. The procedures to convert this data into the ARC/INFO data base will be developed. The data base will be used to analyze the spatial and temporal data.

RESULTS: Bench marks have been established and an overflight was accomplished to provide an accurate base map of ARDEC for a base map in ARC/INFO. ARC/INFO modules to integrate data collected with GPS system to be integrated into the GIS layers. Conversions can be made between ALBERS, State Plane or Universal Transverse Mercator System projections. A MAPBUILDER module permits the user to display the point coverage and create map compositions combining as many coverages as desired for displaying and printing. A module has also been completed that will process the remotely sensed relectance data and transfer to ARC/INFO

FUTURE PLANS: The map information will be used as input to the linear move irrigation system for applying variable water and chemicals. This will require mapping the desired applications into the control language of the irrigation system which has been partially completed. An irrigation scheduling program is nearly completed to use the variable information and allocates the water. Maps will be output to illustrate the required irrigations and the allocation of the available water supply. MapInfo has been added to the available programs for potential use in site specific farming.

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[8]Dept. of Horticulture, Colo. State Univ.

CHARACTERIZING WEED POPULATIONS IN NEBRASKA SOYBEAN FIELDS FOR MORE EFFICIENT MANAGEMENT

D. A. Mortensen[9], L. J. Wiles, and E. E. Schweizer

PROBLEM: Several herbicides are reaching groundwater and surface water from routine agricultural use. In the corn belt, soybean herbicides have been detected in groundwater and seasonally in surface water. More efficient management of weeds in soybean fields can enhance the quality of groundwater and surface water by reducing the use of herbicides.

APPROACH: Intensive field surveys were conducted in farmer's fields to determine the spatial distribution of composite broadleaf and grass weed seedlings in 17 corn and 15 soybean fields in eastern Nebraska between 1993 and 1995. All fields had herbicides applied in a 15-inch band over 30-inch spaced rows. Two county extension agents and two crop consultants were involved in field selection and in coordinating follow-up visits to each site. Weed populations were determined in the interrow and band-treated intrarow. The weed population data was used to construct spatial maps that revealed the area occupied by weeds in each field.

RESULTS: Spatial maps constructed for grass and broadleaf weeds revealed that individual species, as well as species assemblages, are highly aggregated, and aggregation generally increases as weed density decreases. The negative binomial distribution consistently fit broadleaf and grass weed populations across time and space for the four fields sampled over four years. The k parameter for this distribution was stable across weed density for each species in a given field with the exception of foxtail populations. Stability of the k parameter was assessed using the likelihood ratio test. There was no stable or common k value over space and time for all weed species. Variability of k was greatest between interfields. Understanding the nature and extent of this variability is critical to developing parametric sequential sampling strategies. The results of these distribution studies indicate that herbicide use could be substantially reduced if weed distribution maps or real-time plant sensing were available to provide information for applying herbicides only to those portions of fields where weeds are present

FUTURE PLANS: In addition to fitting numerical distribution models to the data, the weed population data will be used to test parametric sequential sampling based on multistage estimation of the negative binomial. This work represents a particular approach to developing a sampling methodology that could be used by consultants for weed scouting. This Specific Cooperative Agreement will terminate on September 30, 1996.

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[9]Dept. Agronomy, Univ. of Nebraska

WEED SEEDBANK AND WEED POTENTIAL UNDER A LINEAR MOVE IRRIGATION SYSTEM AT ARDEC

E.E. Schweizer and L.J. Wiles

PROBLEM: Weed control with herbicides is economic, convenient and effective. However, the prophylactic use of herbicides to control annual weeds has been the norm rather than the exception. Consequently, some herbicides have been detected in surface and ground water. Water quality could be enhanced by reducing the use of herbicides, and weed management could be more efficient if growers had more accurate, field-specific information about the composition and spatial distribution of weed populations. Applications of herbicides via a linear move sprinkler would be more efficient if they were applied only where weeds exist.

APPROACH: The 24 research plots under the linear move and surge irrigation systems at ARDEC were sampled for weed seedbank and weed seedling populations, and for seed production of three annual weed species (green foxtail, toothed spurge, and barnyardgrass). After corn emergence, soil cores were collected at forty five sites, using a grid of 5 (rows) by 9 (sites/row). Soil samples were elutriated and weed seed identified and counted. Weeds were counted, by species, at the same sites three weeks after emergence and again in the fall.

RESULTS: *Linear system*: The average seedbank density in the plots not treated with herbicides was 1015 seed m^{-2} compared to 710 seed m^{-2} in plots treated with herbicides. The seedbank of the five major annual weed species in descending order were: redroot pigweed, green foxtail, toothed spurge, barnyardgrass, and nightshade. Toothed spurge was the principal species present in both the untreated and treated plots after corn emergence. *Surge system*: The average seedbank density in the plots not treated with herbicides was 600 seed m^{-2} compared to 615 seed m^{-2} in plots treated with herbicides. The seedbank of the five major annual weed species in descending order were: barnyardgrass, redroot pigweed, toothed spurge, green foxtail, and kochia. *Both systems*: Toothed spurge was the principal species that emerged in corn in both systems irrespectively of whether herbicides were applied or not. Seed production of the three selected annual weed species has not yet been determined.

FUTURE PLANS: Maps of the seedbank will be made for each linear and surge irrigation plot. Information on seedbank densities will serve as a useful database for making future weed management decisions based on the bioeconomic weed/corn model GWM. Based on computer simulations and weed population dynamics, spatially variable rates of herbicides will be able to be applied when the linear move sprinkler irrigation system is plumbed for chemigation or with a conventional sprayer for the surge irrigation system.

DEVELOPMENT OF A GENERAL, PHYSICALLY-BASED INFILTRATION/REDISTRIBUTION MODEL

R.E. Smith, C. Corradini[10], and F. Melone[10]

PROBLEM: Previous infiltration models have made significant implicit assumptions on the rainfall pattern, generally, that it is always greater than infiltration capacity, or it is always less. Many rainfall events fail to meet this criteria, and at a point in an irrigated field, there may be a complex pattern of water application, including sprinkler input as well as flooded surface conditions. In addition, most existing infiltration models are quite inaccurate for very wet initial conditions, such as will be the case during a sequence of wetting events, or during surge irrigation. A model is needed which will reflect soil physical parameters and which will estimate intake rates for any pattern of rainfall rates at the surface, including estimation of the recovery of infiltration capacity for periods of no input, or low input rates.

APPROACH: A numerical solution of the dynamic equations for soil water flow was used as a robust model for the response of a soil profile to a variety of inputs. Analytic approaches were investigated, developed by making certain simplifications regrading the wetting profile. One approximation was based on assuming the soil wetting profile to be an expanding, scalable shape with geometric similarity. This assumption was useful for the case where the wetted profile is redistributing during periods of low or no rain. A new formulation of the 3-parameter infiltration model was developed to accurately model infiltration after a soil profile becomes wet (wet initial conditions). Results with analytic approximations for the soil flow equations were compared with the Richards' equation solutions..

RESULTS: Recently, a unified analytic method was developed which can be used for prewetting as well as redistribution. The model requires very basic parameters to characterize a soil, including the saturated hydraulic conductivity, the parameter known as the effective capillary drive, the initial water deficit, and some estimate of the pore size distribution of the soil. This last value is measured by a pore-size distribution index, which is large for uniform particle sizes, and small for soils with a large distribution of particle sizes A series of tests on several soil types and several cases was conducted, including a variety of patterns of rainfall rates, some having the potential to cause runoff, and some not. The new analytic method is quite adequate for a range of conditions and a range of soil types. It is being implemented in hydrologic and irrigation models.

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[10] IRPI, National Research Council, Perugia, Italy

STUDY OF THE BULK STATIC AND DYNAMIC PROPERTIES OF A HETEROGENEOUS SOIL ENSEMBLE

R.E. Smith, B. Diekkrüger[11], and Y. Zhang

PROBLEM: The practical application of physics of soil water flow has depended on the models and equations developed and tested on relatively homogeneous soil columns where conditions can be made simple for testing hypotheses, and demonstrating, for example, Darcy's Law. However, research continues to reveal the fact that for a large area, even where there is no observable change in soil type, soil properties are heterogeneous, and a certain amount of random variation is to be expected. Practical problems are almost always concerned with large areas which contain this heterogeneity, so a difficulty in application of soil physics, called "scaling up", must be addressed. This study attempts to assess the large scale behavior of a soil in terms of the vertical flow of water, treating the area as composed of an ensemble of a large number of samples.

APPROACH: We studied soils with randomly varying parameters that describe the retention (relation of water content θ to matric pressure head ψ) and the conductivity curves (relation of conductivity, K, to ψ). Measured data from an extensive sampling study in Germany and another in New Mexico is used to establish hypotheses concerning parameter distributions and independence, which allows simulations of the ensemble behavior. Measurements are also taken locally to establish the scale of heterogeneity at ARDEC. The ensemble (large scale) retention and conductivity curves (ψ-θ-K relations) can be established by simulation, given the sampling values of the distributions. A stratified sampling or multidimensional Latin Hypercube method was used with a numerical solution of Richards' equation to establish the relation of the ensemble dynamic behavior to that of a soil with the mean parameters, or a soil with the static ensemble characteristics. A similar approach is used to look at an aerially integrated infiltration model.

RESULTS: A thesis study has looked briefly at the heterogeneity exhibited at the ARDEC experimental site, and the effect of heterogeneity on measurements of a disk permeameter. A double ring disk permeameter has been developed and tested, which gives values of one-dimensional flux. Methods for analysis of disk permeameter results have been developed, and effects of soil crusts on such measurements evaluated. A model for infiltration with spatially variable saturated conductivity, K_s, has been developed, and is being used in the research hydrologic model KINEROS2. It approximates the net infiltration rate over an area, and is applicable to a pattern of rates such as a rainstorm. This method requires only the additional input of the coefficient of variation of K_s.

FUTURE PLANS: Existing simulation models such as Opus should be modified to account for the demonstrated bias due to even mild amounts of spatial heterogeneity, thus to make them more appropriate for representing larger areas.

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[11]Inst. für Geoökologie, Techn. Univ. Braunschweig, Germany

DEVELOPMENT AND APPLICATION OF A DYNAMIC SOIL EROSION MODEL

R.E. Smith, D.C. Goodrich[12], J.N. Quinton[13], and G. Govers[14]

PROBLEM: Whenever there is water running on the soil surface, from whatever source, erosion of soil can be a problem. Soil erosion represents loss of nutrients, and an economic loss to farmers. This is a complex and difficult process to model, and prediction of erosion for a given flow, soil and topographic condition has been a source of study for some time. Recognizing the complexity of the phenomenon, almost all current methods are approximate, either by spatial or temporal lumping of variability, or by simply using regression estimates as is done in the USLE and RUSLE methods. There is a need to study the erosion process in its full dynamic, spatially variable condition, to develop better estimating models, and to evaluate the assumptions made by more approximate methods.

APPROACH: Erosion is considered, in our research, to be a transport process intimately linked to the conditions of flowing water and rainfall rate. As a transport process, there are fundamental relations of the transport capacity, the treatment of local input sources, and the functions of entrainment and deposition of material. The spatially distributed simulation of runoff velocities, depths, and slopes which are part of the kinematic wave runoff models such as KINEROS can be used directly to simulate spatially distributed values of entrained soil concentration. Rainfall energy at the soil surface is used to estimate the sediment dislodged by rainfall, and runoff models which include descriptions of plant and cobble cover can reflect their influence directly. Sediment transport capacity is considered a dynamic balance between continuous processes of erosion and deposition, simplifying the estimation of hydraulic processes.

RESULTS: An improved, multi-particle size erosion model has been included in the model KINEROS2. This model provides for limiting of erodibility for a range of particle sizes, based on the least erodible size in the soil mix. Research is ongoing to evaluate a 'best fit' shallow-flow transport equation based on shallow flow flume experimental data.

FUTURE PLANS: Several new graduate students are working with us, and it is hoped that one can become interested in studying the unsolved problem of the distribution of transport energy among a range of particle sizes.

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[12] ARS Southwest Watershed Research Center, Tucson, AZ. [13] Silsoe College, Silsoe, England. [14] Catholic University of Leuven, Leuven, Belgium

PROTECTING WATER QUALITY BY SCOUTING WEED POPULATIONS

L.J. Wiles and E.E. Schweizer

PROBLEM: Weed control with herbicides is economic, convenient and effective. As a result, herbicides have lead the dramatic increase in the amount of pesticide applied. Approximately 70% of the total amount is applied to corn and soybean. Several herbicides are commonly detected in surface water and groundwater in the corn belt. Water quality could be enhanced by reducing the use of herbicides, and weed management could be more efficient if growers had more accurate, field-specific information about the composition and spatial distribution of weed populations. Thus, a 2-year field study was conducted in Colorado to develop scouting plans for obtaining the information about weed populations needed to use computer weed management models.

APPROACH: Weed seed bank and seedling populations were sampled in four pivot irrigated and four furrow irrigated commercial corn fields in eastern Colorado in 1993 and 1994. These fields were located on different sites each year. Before corn emergence, 1245 soil samples were collected on a square grid pattern in a 20-acre block. After corn emergence, weed seedlings were identified in a five foot length of crop row adjacent to each sample site. Time required for soil sampling and seedling counts was recorded.

RESULTS: The seed and seedling counts have been analyzed and mapped. Seedling populations consisted of 9 to 23 species in a field and seedbanks consisted of 7 to 19 species. However, just 2 to 6 species made up 90% of the seedbank or seedling population in a field. Spatial distributions were patchy and the counts had highly skewed distributions. The frequency distribution of counts could be described with a logarithmic with zeroes distribution in 26 of 104 cases for seeds and 23 of 94 cases for seedlings. A negative binomial distribution described the frequency distribution of counts in 23 cases for seeds and in 31 cases for seedlings. Based on the fitted distributions, the proportion of a field free of broadleaf weeds is estimated to range from 1 to 81%. From 11 to 50% of a field was estimated to be free of grass weeds. Maps indicate that the pattern of patchiness varied between fields. Maps of seedling and seedbank populations in a field were similar, although the correlation between seed and seedling counts was low. One objective of our research is to determine the cost of scouting seed and seedling populations. The time required to count the seeds in a soil core or seedlings in the quadrat was weakly related to density with large variation between individuals. For seeds, counting was more time consuming when the soil had a moderate to high sand content.

FUTURE PLANS: In 1996, we will conduct stochastic simulations based on our data and data from seedling studies in Nebraska to identify cost-effective scouting plans and to determine the value of spatially-variable weed management. We plan on meeting with at least three groups of consultants and growers to learn about current weed scouting practices. This information will help us develop scouting plans to be tested in the simulations.

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